PROJECTION OF GREENHOUSE GAS EMISSIONS 2009 TO 2030

NERI Technical Report no. 793 2010

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Data sheet

Series title and no.: NERI Technical Report no. 792

Title: Projection of Greenhouse Gas Emissions 2009 to 2030

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Department: Department of Policy Analysis

Publisher: National Environmental Research Institute ©
Aarhus University - Denmark

URL: http://www.neri.dk

Year of publication: September 2010
Editing completed: August 2010
Referee: Erik Rasmussen, Danish Energy Agency

Financial support: Danish Energy Agency

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

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 basic scenarios together 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 the 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 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 and SF_6

Layout and front page photo: Ann-Katrine Holme Christoffersen

ISBN: 978-87-7073-188-1
ISSN (electronic): 1600-0048

Number of pages: 143

Internet version: The report is available in electronic format at NERI's website
http://www.dmu.dk/Pub/FR793.pdf

Contents

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 basic scenarios, which include the estimated effects on Denmark's greenhouse gas (GHG) emissions of policies and measures implemented until April 2010 ('with measures' projections). Not all sectors have been updated compared to previously published 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.

The authors would like to thank:

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

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

The Faculty of Agricultural Sciences, Aarhus University and the Knowledge Centre for Agriculture, the Danish Agricultural Advisory Service (DAAS) for providing data for the agricultural sector.

The Danish Environmental Protection Agency (DEPA) for partly financially supporting the work on solvent projections.

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 on Denmark's GHG emissions of policies and measures implemented until April 2010 ('with measures' projections). For activity rates, 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 plants in Denmark. The projection models are 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 predicted to be Energy Industries (36 %), Transport (22 %), Agriculture (17 %), and Other Sectors (11 %). For Other Sectors the most important source is fuel use in the residential sector (Figure S.1). GHG emissions show a decreasing trend in the projection period from 2009 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 59 843 ktonnes CO_2 equivalents and 53 978 ktonnes in 2030, corresponding to a decrease of about 10 %. From 1990 to '2010' the emissions are estimated to decrease by about 13 %.

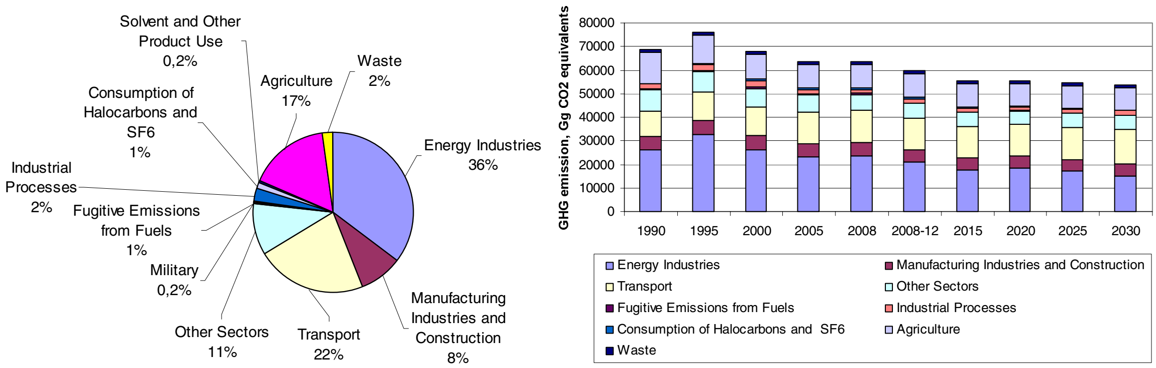


Figure S.1 Total GHG emissions in CO_2 equivalents. Distribution according to main sectors ('2010') and time-series for 1990 to 2025.

Stationary combustion

The GHG emissions in '2010' from the main source, which is public power generation (60 %), are estimated to decrease significantly in the period from 2008 to 2030 due to 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 60 % 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 20 % from ‘2010’ to 2030.

Industrial processes

The GHG emission from industrial processes increased during the 1990s reaching a maximum in 2000. Closure of the nitric acid/fertiliser plant in 2004 has resulted in a considerable decrease in the GHG emission and stabilisation at a level of about 1,500 ktonnes CO_2 equivalents. The most significant source is cement production, which contributes with 87 % of the process-related GHG emission. Most of the processes are assumed to be constant at the same level as in 2008. 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 cement production.

Solvents

The projection for solvents has not been updated since 2008, therefore the projected emissions are not totally consistent with the latest historical data.

In 2006 solvent and other product use account for 0.3 % of the total CO_2 emissions. Emission projections from 2006 to 2010 are based on linear projections of 1995 – 2006 historical data and projections of four industrial sectors, namely “Auto paint and repair”, “Plastic industry”, “Graphic industry” and “Lacquer and paint industry”, comprising approximately 27 % of the total GHG emission from solvent and other product use in ‘2010’. Constant emissions are assumed from 2010 to 2030. Households, construction, plastic industry, industrial mass produced products and auto paint and repair and are the largest sources to the Danish Volatile Organic Compounds (VOC) emissions from solvent use.

Transport

Road transport is the main source of GHG emissions in ’2010’ and emissions from this sector are expected to increase by 43 % 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 31 % to 25 %. For agriculture/forestry/fisheries the emissions increase by 13 % from 1990 to 2030. For this sector, the emissions reduce from 1990 to 2005 due to smaller numbers of agricultural tractors and harvesters though with larger engines. For industry (1A2f), the emissions increase by 35 % from 1990-2030. For this sector there is a significant emission growth from 1990-2008 (due to increased activity), followed by an almost constant level of GHG emissions from 2008 onwards, due to gradually more fuel efficient machinery, which outbalances a small increase in activity in terms of emission impact.

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 dominant f-gases, which in '2010' are expected to contribute with 92 % of the f-gas emission.

Agriculture

The projection of emissions from agriculture has not been updated in connection with this project.

From 1990 to 2008, the emission of GHGs in the agricultural sector has declined from 13,109 ktonnes CO_2 equivalents to 10,025 ktonnes CO_2 equivalents, which corresponds to a 24 % reduction. This development continues and the emission is expected to fall further to 9,363 ktonnes CO_2 equivalents in 2030. The reduction both in the historical data and the projection can mainly be explained by improved utilisation of nitrogen in manure and a significant fall 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 the stable and expansion of biogas production are taken into account in the projections but do not contribute to significant changes in the total GHG emission.

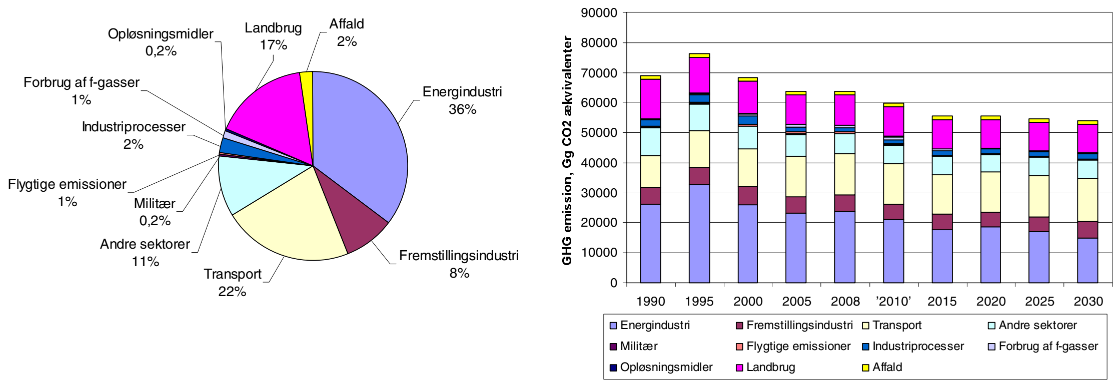
Waste

The total historical GHG emission from the waste sector has been slightly decreasing since 1990. The level predicted for '2010' and onwards is rather stagnant compared to the latest historic year. In '2010', CH_4 from landfill sites is predicted to contribute with 85 % of the emission from the sector as a whole. From '2010' no further decrease in the CH_4 emission from landfill is foreseen; an almost constant emission level is predicted. An almost constant level for CH_4 emission from wastewater in the period considered is foreseen, while the N_2O emission from wastewater is forecasted to slightly increase; the contributions to the sector of these emissions in '2010' being 12 %.

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 scenarium, som medtager de estimerede effekter på Danmarks drivhusgasudledninger af virkemidler iværksat indtil april 2010 ('med eksisterende virkemidler'fremskrivninger). 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 referer 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 (36 %), transport (22 %), landbrug (17 %), 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 2009 til 2030. Generelt falder emissionsandelen for energisektoren, mens emissionsandelen for transportsektoren stiger. De totale emissioner er beregnet til 59.843 ktons CO_2 ækvivalenter i '2010' og til 53.978 ktons i 2030 svarende til et fald på omkring 10 %. Fra 1990 til '2010' er emissionerne beregnet til at ville falde med ca. 13 %.



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

Stationær forbrænding

Drivhusgasemissionen fra kraft- og kraftvarmeværker, som er den største kilde i '2010' (60 %), er beregnet til at falde markant i perioden 2009 til 2030 grundet et delvis brændselsskift fra kul til træ og affald. Emissionerne fra husholdningers forbrændingsanlæg falder ifølge fremskrivningen også og bliver næsten 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 20 % fra '2010' til 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 og den har stabiliseret sig omkring 1500 ktons CO_2-ekvivalenter. Den væsentligste kilde er cementproduktion, som bidrager med mere end 87 % af den procesrelaterede drivhusgasemission. De fleste procesemissioner er antaget at være konstante på samme niveau som 2008. 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

CO_2-emissioner fra anvendelse af opløsningsmidler udgør 0,3 % af de samlede danske CO_2-emissioner. Fremskrivningen fra 2006 til 2010 er baseret på lineære fremskrivninger af historiske data samt fremskrivninger af fire brancher: Autobranchen, plastbranchen, grafisk industri og lak- og farveindustrien. Sidstnævnte udgør tilsammen ca. 27 % af de samlede CO_2-emissioner fra anvendelse af opløsningsmidler. Der antages konstante emissioner fra 2010 til 2030. Husholdninger, byggesektoren, plastindustrien and industrielt masseproducerede produkter er de største kilder til CO_2-emissioner fra anvendelse af opløsningsmidler.

Transport

Vejtransport er den største emissionskilde for drivhusgasser i '2010', og fra 1990 til 2030 forventes emissionerne at stige med 43 % pga. trafikkens vækst. Den samlede emission for andre mobile kilder er noget lavere end vejtransporten totalt, og fra 1990 til 2030 falder andre mobile kilders emissionsandel fra 31 til 25 %. For landbrug/skovbrug/fiskeri bliver emissionerne 13 % større i samme periode. Emissionerne for denne sektor falder fra 1990 til 2005, hovedsageligt pga. et fald i antallet af traktorer og mejetærskere. For industri stiger emissionerne med 35 % fra 1990 til 2030. Fra 1990-2008 stiger emissionerne markant pga. øget aktivitet, hvorefter emissionerne falder en smule pga. gradvist mere energieffektive motorer.

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' bidrager med 92 % til den samlede F-gas-emission.

Landbrug

I perioden fra 1990 til 2008 er emissionen af drivhusgasser faldet fra 13.109 ktons CO_2 ækvivalenter til 10.025 ktons CO_2 ækvivalenter, hvilket svarer til en reduktion på 24 %. Denne udvikling forventes at fortsætte og emissionen forudses at falde yderligere til 9.363 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 stalden og en øget vækst i biogasanlæg, men disse tiltag har ikke en væsentlig indflydelse på den totale emission.

Affald

Affaldssektionens samlede drivhusgasemissioner har i de historiske opgørelser vist et mindre fald siden 1990. Fremskrivningen viser, at for '2010' og derefter er de samlede emissioner stagnerende, dog med en svag stigning, i forhold til det seneste historiske år (2008). I '2010' forventes CH_4 fra lossepladser stadig at dominere sektoren og udgøre 85 % af hele sektorens emissioner. Fra '2010' er der forudset et lille fald eller stagnation i CH_4-emissioner fra lossepladser. CH_4 fra spildevand er forudset at være nær konstant, mens N_2O fra spildevand ser ud til at stige lidt, således at bidraget af disse emissioner til sektorens samlede emission i '2010' er 12 %.

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). The purpose of the present project, "Projection of greenhouse gas emissions 2009 to 2030" has been to update the emission projections for selected sectors based on the latest national energy projections, other relevant activity data and emission factors.

1.1 Obligations

In relation to the Kyoto Protocol, for the period 2008-2012 the EU has committed itself to reduce emissions of GHGs to 8 % (on average) below 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 at 21 % as an element of the burden-sharing agreement within the EU[1]. 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 in 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 2010 are included in the projections and the projection of total GHG emissions is therefore a so-called 'with 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] In the Council's decision on the EU ratification to the Kyoto Protocol, the commitments of the different Member States are thus given as percentages compared to the base year. In connection with the Council decision, the Council (environment) and the Commission have, in a joint statement, agreed e.g. to show consideration in 2006 for Denmark's remarks to the Council conclusions of 16-17 June 1998 concerning emissions in the base year. However, in 2006 it was decided that the consideration will not take place until after the review of all EU initial reports on assigned amount under the Kyoto Protocol. Although the review of all EU initial reports was finalised in 2008, a proposal has not yet been put forward by the Commission.

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 370 ppm (about 30 %) since the pre-industrial era in the nineteenth century (IPCC, Third 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 150 % and 16 %, respectively (IPCC, 2001). 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 (Nielsen et al., 2010). Figure 1.1 shows the estimated total GHG emissions in CO_2 equivalents from 1990 to 2008. 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 emission by forestry and soil in 2008 was 4 % of the total emission in CO_2 equivalents. The national total GHG emission in CO_2 equivalents excluding LULUCF has decreased by 7.4 % from 1990 to 2008 and increased 4.0 % including LULUCF.

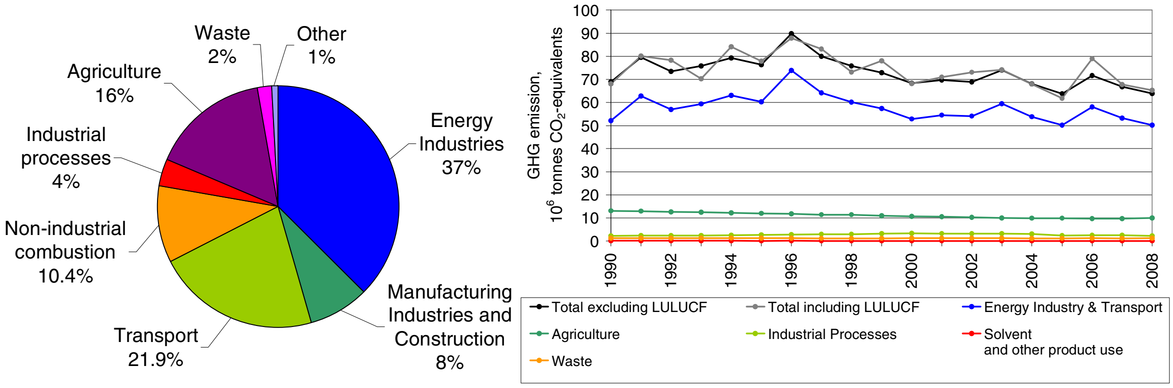


Figure 1.1 Greenhouse gas emissions in CO_2 equivalents distributed on main sectors for 2008 and time-series for 1990 to 2008.

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 47 % of the emissions. About 27 % come from the transport sector. The main reason for this increase was export of electricity. In 2008, the actual CO_2 emission was about 0.3 % higher than the emission in 1990.

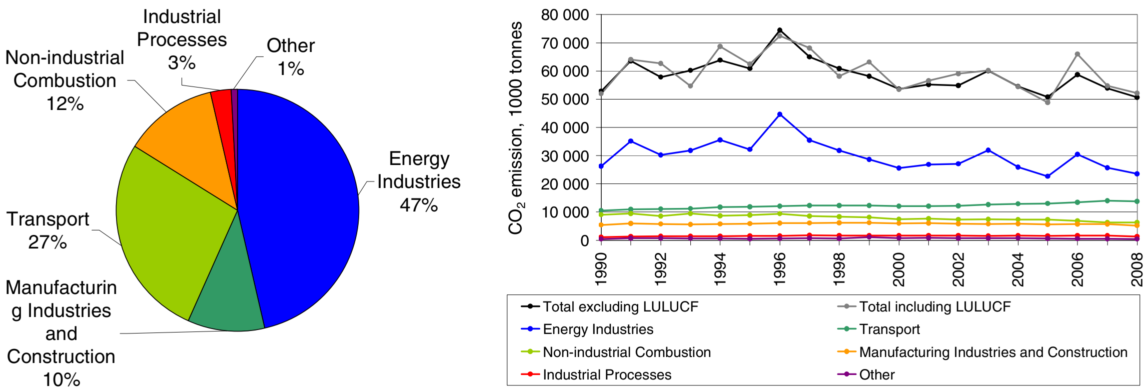


Figure 1.2 CO_2 emissions. Distribution according to the main sectors (2008) and time-series for 1990 to 2008.

1.3.2 Nitrous oxide

Agriculture is the most important N_2O emission source in 2008 contributing 91 % (Figure 1.3) of which N_2O from soil dominates (83 %). 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 % from 1990 to 2008 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 6.5 %. The N_2O emission from transport contributes by 2.1 % in 2008. This emission has 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.

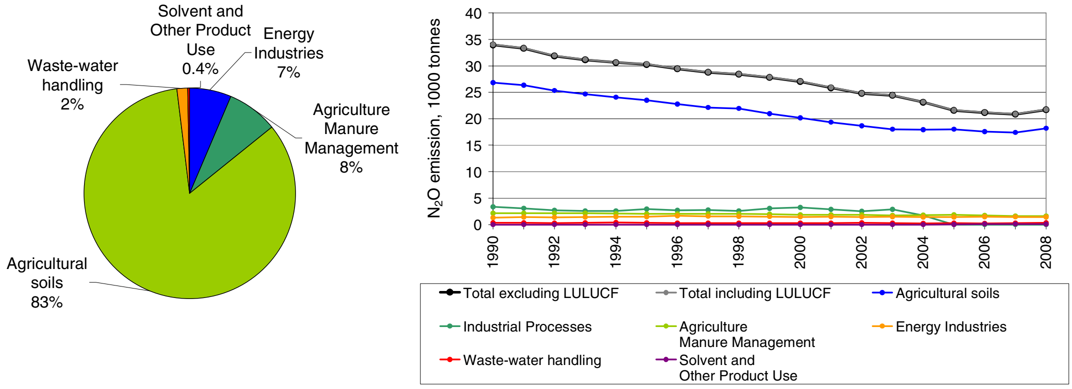


Figure 1.3 N_2O emissions. Distribution according to the main sectors (2008) and time-series for 1990 to 2008.

1.3.3 Methane

The largest sources of anthropogenic CH_4 emissions are agricultural activities contributing in 2008 with 69.6 %, waste (20.0 %), public power and district heating plants (3.3 %), see figure 1.4. The emission from agriculture derives from enteric fermentation (50.7 %) and management of animal manure (18.9 %). 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 2008, the emission of CH_4 from enteric fermentation has decreased 13.5 % due to the decrease in the number of cattle. However, the emission from manure management has in the same period increased 20.8 % due to a change in traditional stable systems towards an increase in slurry-based stable systems. Altogether, the emission of CH_4 from the agriculture sector has decreased by 6.3 % from 1990 to 2008. The emission of CH_4 from waste disposal has decreased slightly due to an increase in the incineration of waste.

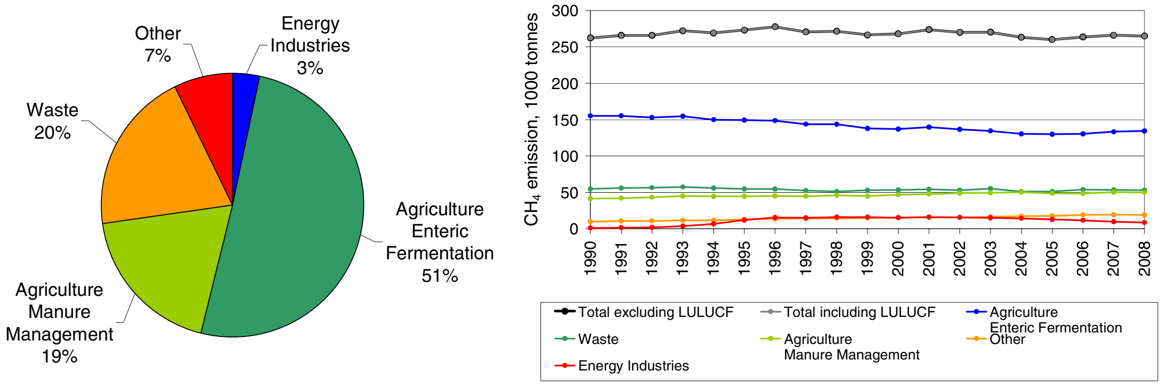


Figure 1.4 CH_4 emissions. Distribution according to the main sectors (2008) and time-series for 1990 to 2008.

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 has been a continuous and substantial increase in the contribution from the range of F-gases as a whole, calculated as the sum of emissions in CO_2 equivalents, see Figure 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. The increase from 1995 to 2008 is 176 %. 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 2008 was only 3.5 %. The use of HFCs has increased several folds. HFCs have, therefore, become dominant F-gases, comprising 66.9 % in 1995, but 95.1 % in 2008. 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.

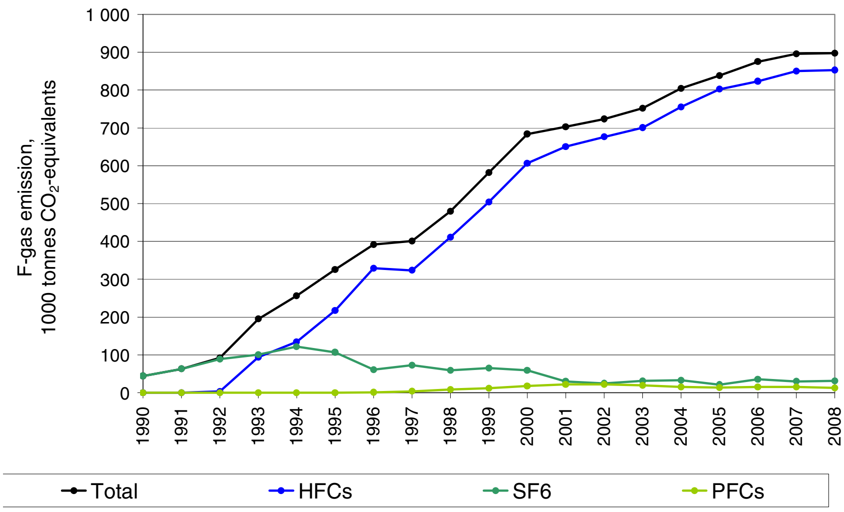


Figure 1.5 F-gas emissions. Time-series for 1990 to 2008.

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

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 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) or the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007) and some are country-specific and refer to Danish legislation, Danish research reports or calculations based on emission data from a considerable number of plants.

Some of the large plants, such as e.g. power plants and municipal waste incineration plants are registered individually as large point sources and emission data from the actual plants are used. The CO_2 from incineration of the plastic part of municipal waste is included in the projected emissions.

2.2 Sources

The combustion of fossil fuels is one of the most important sources of GHGs emissions and this chapter covers all sectors, which use fuels for energy production, with the exception of the transport sector. 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
Flaring	1B2c	09

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 *1A4)*.

Fugitive emissions and emissions from flaring in oil refinery and in gas and oil extraction are estimated in Chapter 3 on fugitive emissions.

As seen in Figure 1.2 in Section 1.3, the sector contributing most to the emission of CO_2 is public power and district heating plants.

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, 2010a) and energy projections for individual plants (Danish Energy Agency, 2010b).

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	2009	2010	2015	2020	2025	2030
Steam coal	172 484	133 480	124 361	129 197	114 086	95 456
Natural gas	170 321	160 633	136 359	134 312	130 221	128 182
Wood and simil.	66 111	74 164	92 992	92 011	100 194	104 828
Municipal waste	38 025	39 642	44 193	49 566	50 620	52 402
Gas oil	20 469	21 069	18 733	15 394	16 057	18 400
Agricultural waste	18 521	20 479	19 155	17 127	17 021	17 116
Residual oil	16 443	12 899	14 547	15 352	15 542	15 003
Refinery gas	14 782	14 782	14 782	14 782	14 782	14 782
Petroleum coke	7053	7281	7607	7480	7939	8494
Biogas	3709	4042	8261	17 801	17 688	17 601
LPG	1369	1418	1466	1519	1648	1802
Coke	890	895	931	909	977	1061
Kerosene	120	121	122	122	124	127
Total	530 299	490 906	483 509	495 571	486 900	475 254

Throughout the period, natural gas and coal are the most important fuels, followed by wood and municipal waste. The largest variations are seen for coal use and renewable energy use. Coal use peaks in 2009 and decreases steadily until 2030. For wood the projected consumption increases throughout the period as a whole and from 2026 onwards the consumption of wood is projected to be higher than the consumption of coal.

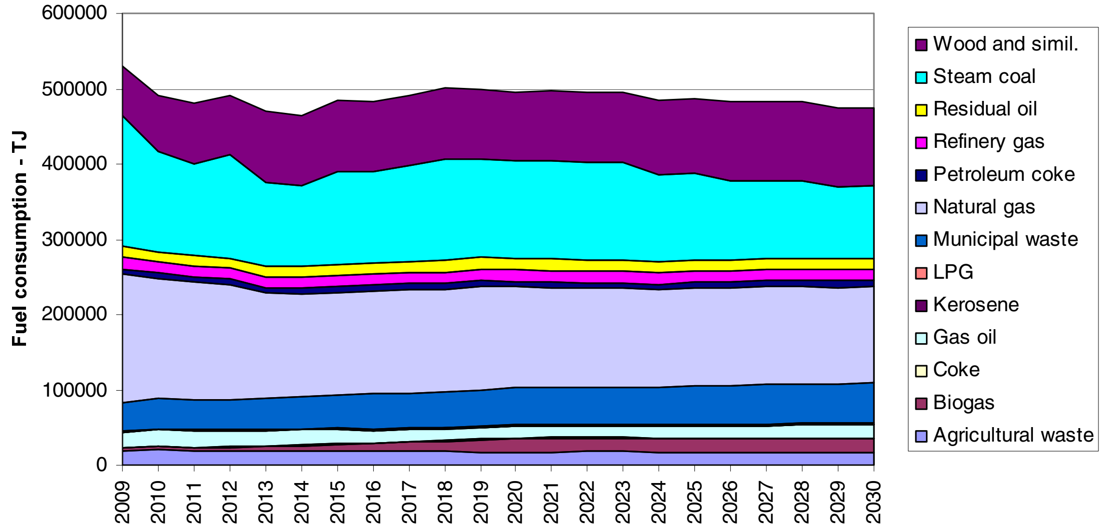

Figure 2.1 Projected energy consumption by fuel type.

Fuel use by sector is shown in Figure 2.2. The fuel sectors consuming the most fuel are public power, industry, residential, off-shore and district heating. According to the energy projection the fuel consumption in the off-shore sector will increase by almost 24 % from 2010 to 2020.

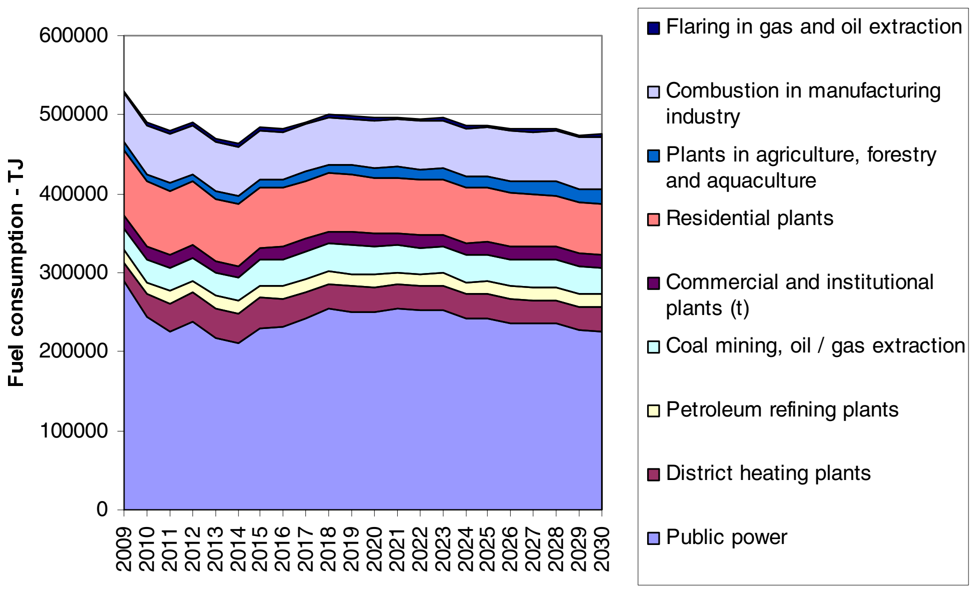

Figure 2.2 Energy use by sector.

Power plants larger than 25 MWe use about 40 % of total fuel, the fuel consumption in these sources decline from 2008 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 consumption decreases. The share of fuel use comprised by exported electricity constitutes 0.1-11 % of total fuel consumption over the period 2009 to 2030 (Figure 2.4).

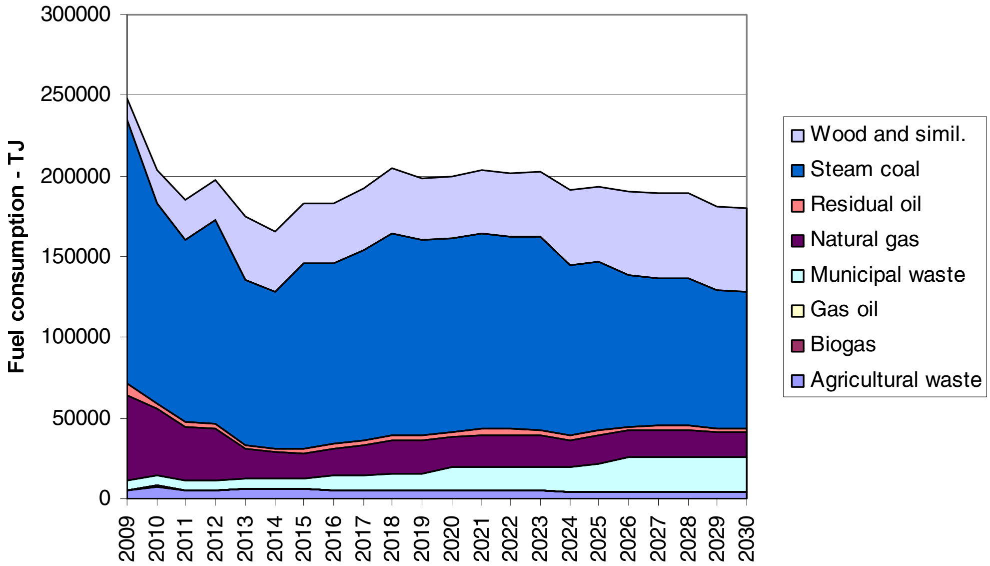

Figure 2.3 Energy consumption for plants > 25 MWe.

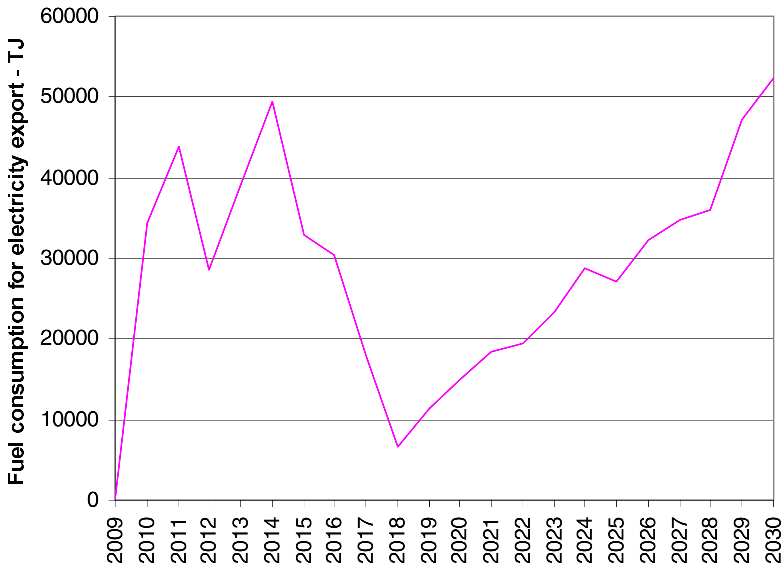

Figure 2.4 Fuel consumption associated with electricity export.

2.4 Emission factors

2.4.1 Area sources

For area sources, emission factors for 2008 have been used (Nielsen et al., 2008). The emission factor for CO_2 is only fuel-dependent. 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.

For biogas and natural gas, however, different emissions factors are used within the majority of SNAP categories. Therefore, Implied Emission Factors (IEF) for these fuels has been calculated for each of the SNAP categories. In calculating these, it is assumed that the distribution of fuel use across boilers, gas turbines and engines within each SNAP category remains the same over the period 2009-2030. If consumption data falls/rises significantly, this is not a good assumption as production from gas engines/gas turbines is linked to district heat sales, whereas production from certain larger power plants is not. This, however, is thought not to be the case with the energy projections here.

The calculated Implied Emission Factors (IEF) for natural gas and biogas in 2008 are shown in Table 2.3. The IEFs are assumed to remain unchanged over the period 2009-2030 with one exception.

For SNAP 0101, point sources account for a large proportion of the consumption. In the calculation of the IEF for natural gas and biogas, it is assumed that all the plants under SNAP 010101 and 010102 are included as point sources, while SNAP 010103 is included as an area source. This is not entirely correct as SNAP 010103 includes plants < 50MW thermal input, while point sources cover plants larger than $25MW_e$. For gas turbines, a proportion of the consumption of natural gas is included under point sources and in calculating the IEF this fuel consumption is deducted.

In the calculation of IEF for industrial plants, consideration is not similarly given to that a proportion of the consumption is included as point sources.

Table 2.2 CH_4 and N_2O for natural gas and biogas, calculation of Implied Emission Factors (IEF) based on emission factors from 2008 and fuel consumption in 2008.

	SNAP	Fuel	Fuel consumption TJ Boilers	GT	GM	Emission factor g/GJ (projections) Boilers	GT	GM	IEF g/GJ
CH_4	010103 - 5	Natural gas	2444	0	14 578	15	1.7	481	414
CH_4	0102	Natural gas	3093	0	137	15	1.7	481	35
CH_4	0103	Natural gas	-	-	-	-	-	-	-
CH_4	0105	Natural gas	354	27 972	2	15	1.7	481	2
CH_4	0201	Natural gas	10 021	0	801	15	1.7	481	49
CH_4	0202	Natural gas	26 695	0	1212	15	1.7	481	35
CH_4	0203	Natural gas	2021	27	1091	15	1.7	481	177
CH_4	0301	Natural gas	32 518	3735	485	15	1.7	481	20
CH_4	010103 - 5	Biogas	123	0	1496	4	4	434	401
CH_4	0102	Biogas	41	0	14	4	4	434	113
CH_4	0103	Biogas	-	-	-	-	-	-	-
CH_4	0105	Biogas	-	-	-	-	-	-	-
CH_4	0201	Biogas	578	0	417	4	4	434	184
CH_4	0202	Biogas	-	-	-	-	-	-	-
CH_4	0203	Biogas	710	0	155	4	4	434	81
CH_4	0301	Biogas	186	0	209	4	4	434	232
N_2O	010103 - 5	Natural gas	2444	0	14 578	1	1	0.58	0.6
N_2O	0102	Natural gas	3093	0	137	1	1	0.58	1.0
N_2O	0103	Natural gas	-	-	-	-	-	-	-
N_2O	0105	Natural gas	354	27 972	2	1	1	0.58	1.0
N_2O	0201	Natural gas	10 021	0	801	1	1	0.58	1.0
N_2O	0202	Natural gas	26 695	0	1212	1	1	0.58	1.0
N_2O	0203	Natural gas	2021	27	1091	1	1	0.58	0.9
N_2O	0301	Natural gas	32 518	3735	485	1	1	0.58	1.0
N_2O	010103 - 5	Biogas	123	0	1496	2	2	1.6	1.6
N_2O	0102	Biogas	41	0	14	2	2	1.6	1.9
N_2O	0103	Biogas	-	-	-	-	-	-	-
N_2O	0105	Biogas	-	-	-	-	-	-	-
N_2O	0201	Biogas	578	0	417	2	2	1.6	1.8
N_2O	0202	Biogas	-	-	-	-	-	-	-
N_2O	0203	Biogas	710	0	155	2	2	1	1.8
N_2O	0301	Biogas	186	0	209	2	2	1.6	1.8

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 used.

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	2008	2009	'2010'	'2015'	2020	2025	2030
Public power	23 012	29 502	23 279	20 159	20 945	20 821	17 562	13 165	14 581	13 039	11 061
District heating plants	1892	970	293	342	372	767	1000	1398	1178	1098	1057
Petroleum refining plants	908	1387	999	938	923	924	924	924	924	924	924
Oil/gas extraction	546	744	1467	1623	1628	1526	1626	1883	2023	1954	1987
Commercial and institutional plants	1422	1156	920	965	843	871	867	866	865	893	927
Residential plants	5066	5132	4149	3917	3259	3041	2960	2410	2173	2090	1818
Plants in agriculture, forestry and aquaculture	620	730	780	651	436	451	447	465	495	567	820
Combustion in industrial plants	4640	5106	5150	4674	4094	3856	3929	3834	3760	3930	4283
Flaring	302	417	665	501	378	192	249	192	171	171	171
Total	38 407	45 144	37 702	33 771	32 878	32 449	29 563	25 138	26 170	24 667	23 049

The projected emissions in 2008-2012 are approximately 8800 ktonnes (CO_2-equiv.) lower than the emissions in 1990. From 1990 to 2030, the total emission falls by approximately 15 300 ktonnes (CO_2-equiv.) or 40 % 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 2008 (Nielsen et al. 2010).

2.5.1 CO_2 emissions

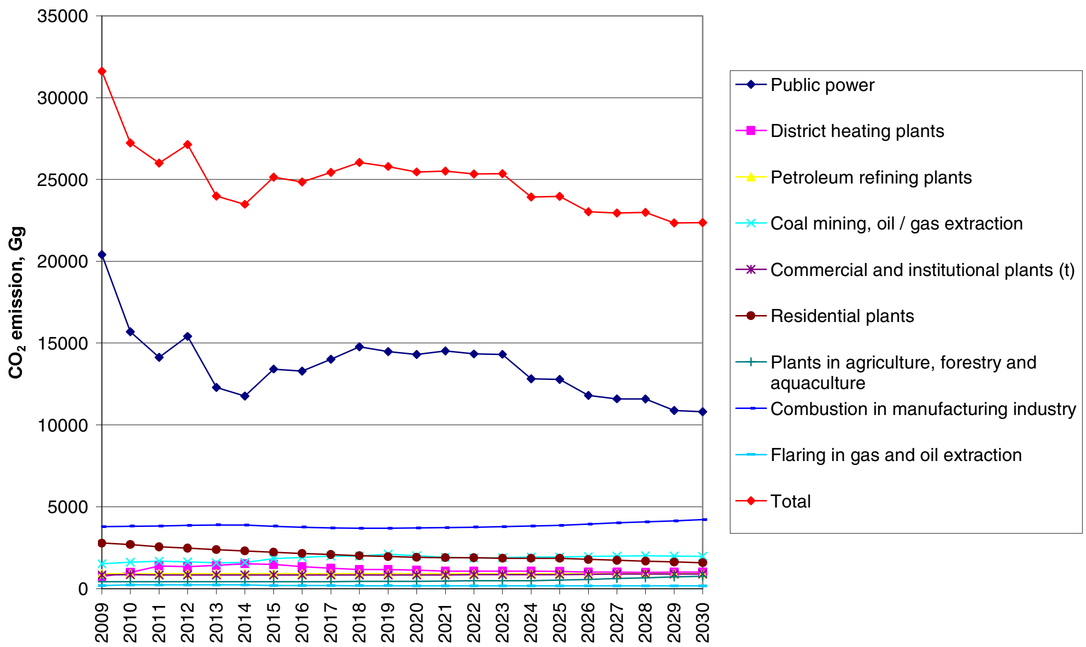

Figure 2.5 CO_2 emissions by sector.

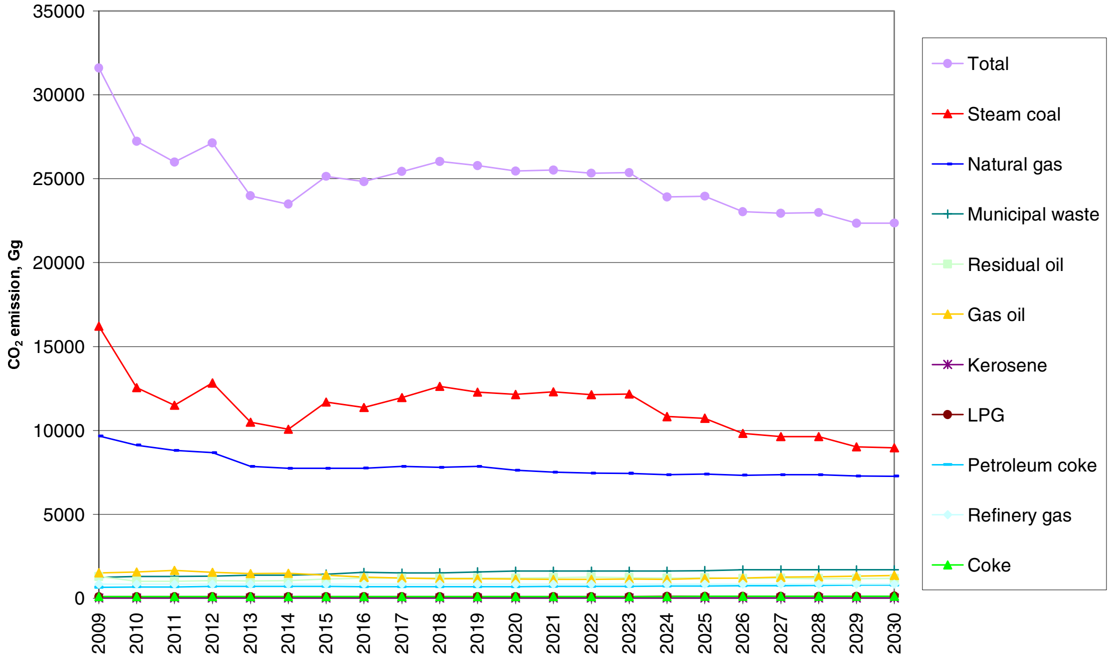

Figure 2.6 CO_2 emissions by fuel.

Table 2.5 CO_2 emissions, Gg.

Sector	1990	1995	2000	2005	2008	2009	'2010'	'2015'	2020	2025	2030
Public power	22 934	29 166	22 863	19 819	20 688	20 413	17 271	12 960	14 310	12 775	10 810
District heating plants	1845	933	273	314	344	732	961	1402	1135	1056	1014
Petroleum refining plants	897	1371	988	927	912	913	913	913	913	913	913
Oil/gas extraction	540	735	1449	1602	1608	1517	1614	1790	2011	1943	1975
Commercial and institutional plants	1405	1132	893	939	818	846	843	842	842	869	903
Residential plants	4946	4989	4003	3712	3012	2779	2702	2230	1924	1847	1583
Plants in agriculture, forestry and aquaculture	594	695	726	606	409	422	418	427	456	523	771
Combustion in industrial plants	4582	5044	5070	4605	4031	3795	3867	3814	3702	3869	4218
Flaring	300	415	662	499	376	191	248	201	170	170	170
Total	38 043	44 479	36 927	33 022	32 199	31 609	28 835	24 578	25 461	23 965	22 357

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 60 % 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 29 % from 2009 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

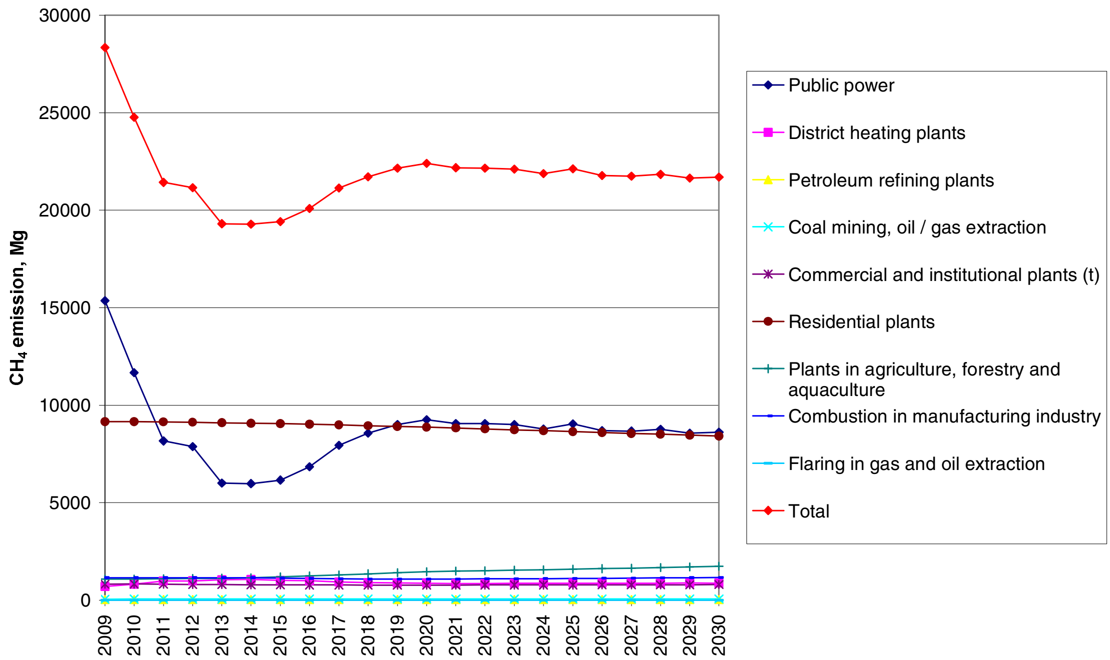

Figure 2.7 CH_4 emissions by sector.

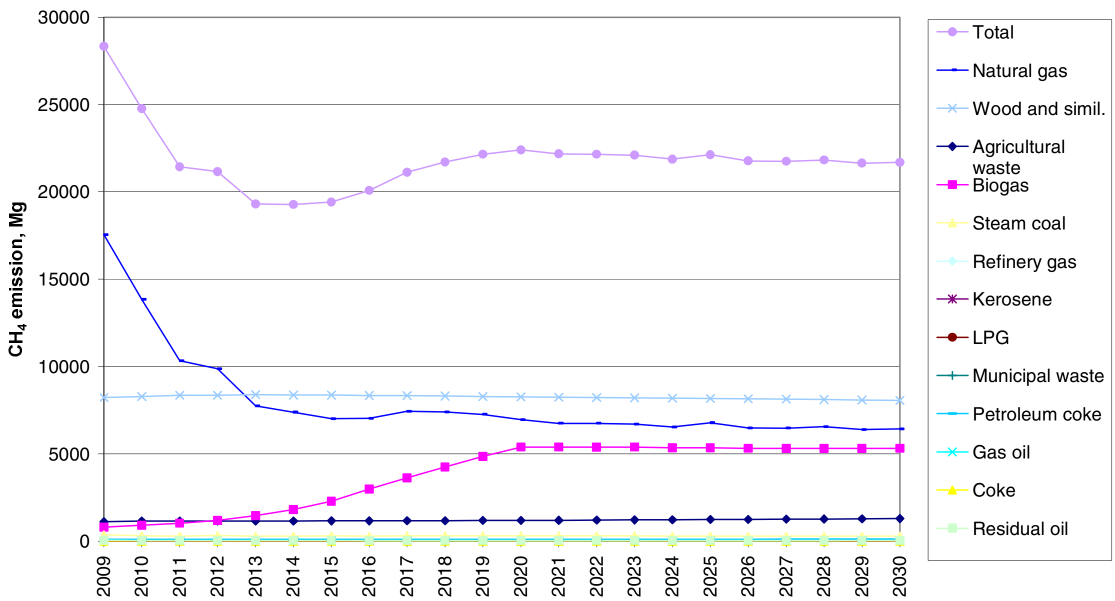

Figure 2.8 CH_4 emissions by fuel.

Table 2.6 CH_4 emissions, Mg.

Sector	1990	1995	2000	2005	2008	2009	'2010'	'2015'	2020	2025	2030
Public power	602	11 155	14 840	12 074	8180	15 358	10 250	6587	9246	9039	8608
District heating plants	464	608	384	633	463	708	790	1009	870	870	879
Petroleum refining plants	32	44	2	2	4	25	21	25	25	25	25
Oil/gas extraction	16	40	58	90	45	51	52	60	67	65	66
Commercial and institutional plants	190	638	929	863	848	816	821	785	771	782	797
Residential plants	3037	4108	4541	6777	8477	9155	9012	9045	8866	8639	8417
Plants in agriculture, forestry and aquaculture	794	1225	2183	1821	1040	1069	1079	1201	1468	1589	1736
Combustion in industrial plants	646	782	1509	1209	971	1148	1112	1126	1081	1111	1158
Flaring	83	63	63	56	47	3	12	4	3	3	3
Total	5864	18 665	24 510	23 525	20 075	28 332	23 150	19 841	22 397	22 122	21 689

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 2008 and the projected emission for 2009 is due to significantly higher estimated fuel consumption in natural gas fuelled gas engines in 2009 than for 2008. 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.

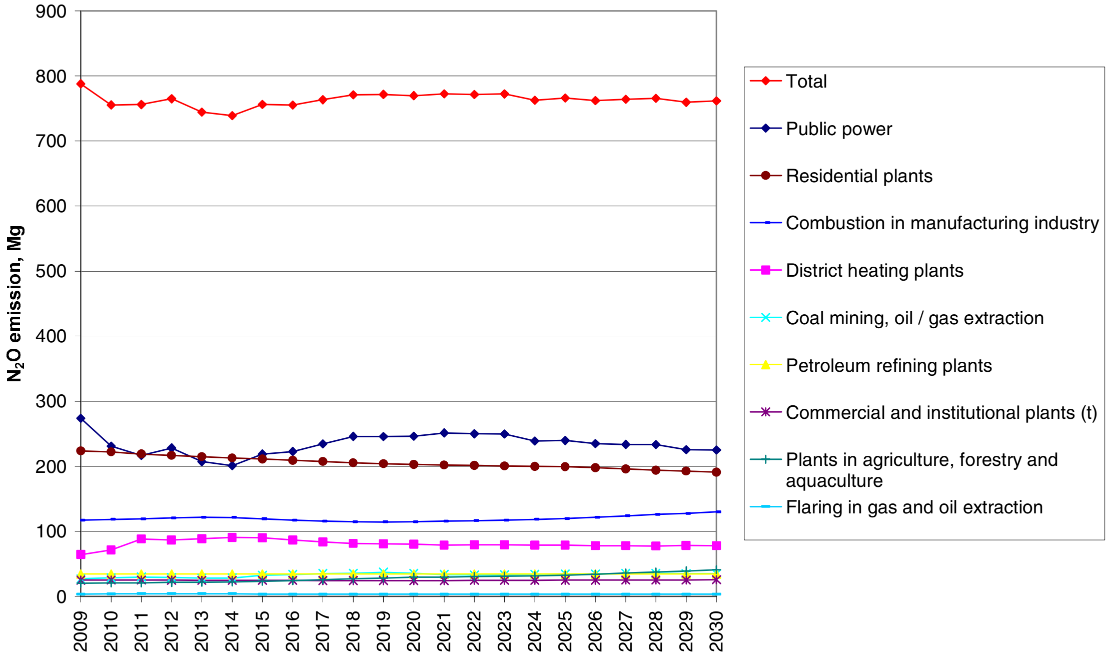

Figure 2.9 N$_2$O emissions by sector.

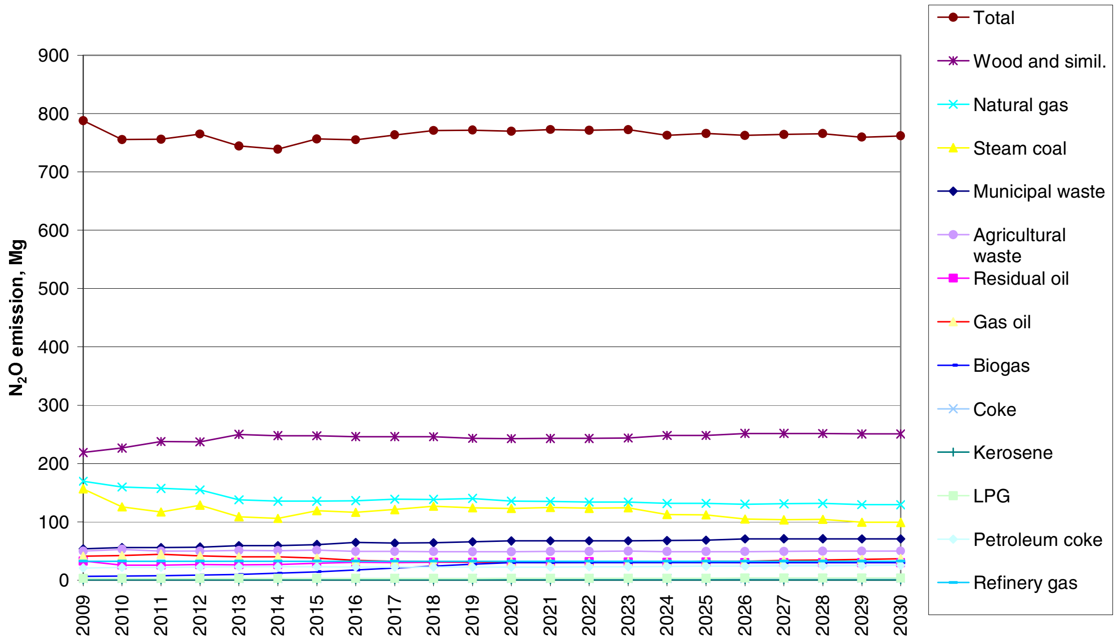

Figure 2.10 N$_2$O emissions by fuel.

Table 2.6 N_2O emissions, Mg.

Sector	1990	1995	2000	2005	2008	2009	'2010'	'2015'	2020	2025	2030
Public power	212	330	338	278	273	274	244	217	246	240	225
District heating plants	120	80	41	49	59	64	74	88	80	79	78
Petroleum refining plants	31	47	35	35	34	34	34	34	34	34	34
Oil/gas extraction	21	28	55	62	62	27	35	32	35	34	35
Commercial and institutional plants	39	32	24	26	22	25	24	24	24	25	25
Residential plants	182	183	163	201	221	224	220	211	203	199	191
Plants in agriculture, forestry and aquaculture	30	28	25	23	19	20	20	23	29	32	41
Combustion in industrial plants	141	148	154	142	137	117	122	119	115	120	130
Flaring	2	3	5	4	3	3	4	4	3	3	3
Total	778	880	840	821	831	788	779	752	770	766	762

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 'Fremskrivning2009-2030 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 'Fremskrivning2009-2030 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 number of summation queries are available in the 'Fremskrivning2009-2030 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.

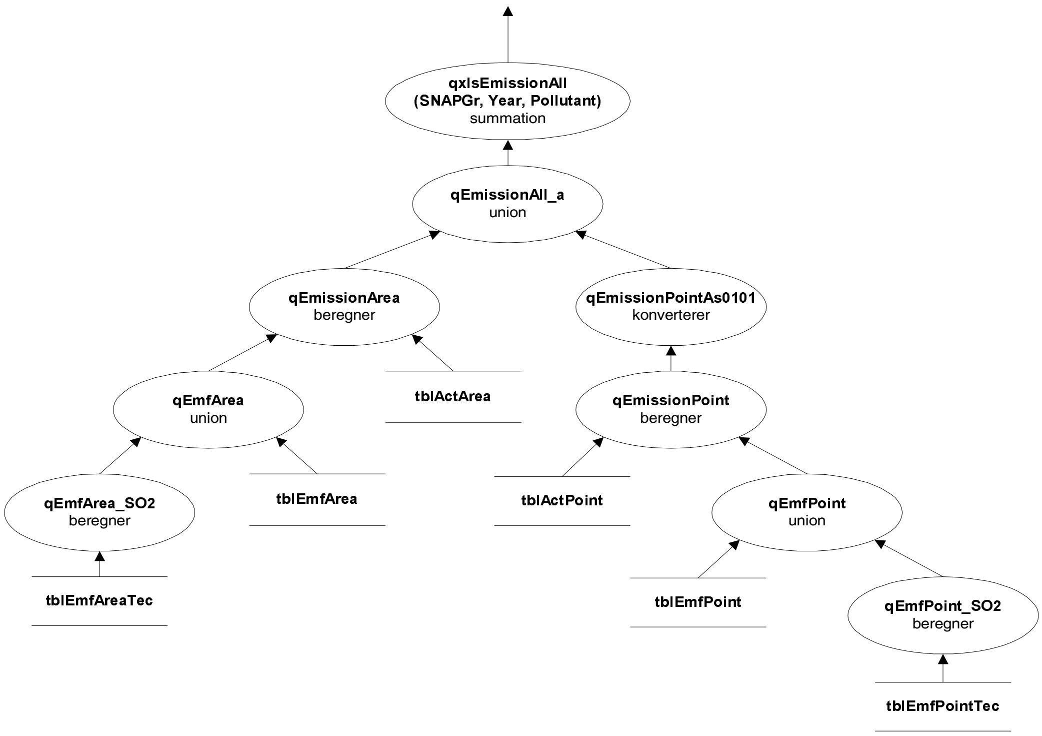

Figure 2.11 The overall construction of the database.

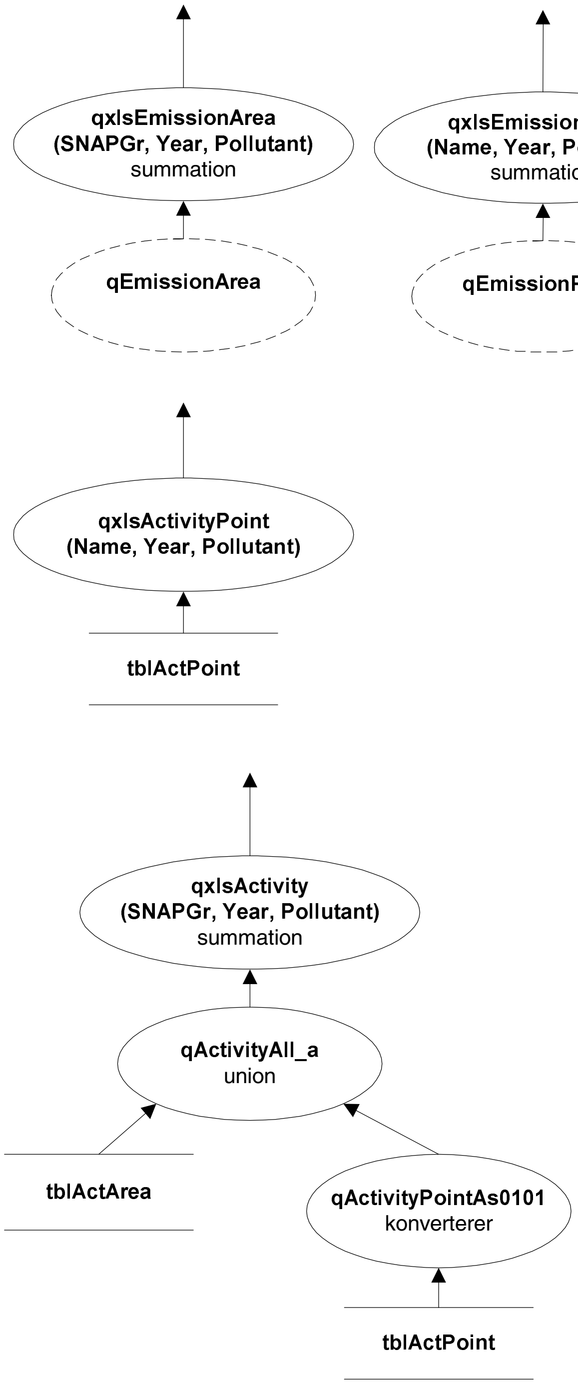

Figure 2.12 Summation queries.

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3 Oil and gas extraction (Fugitive emissions)

This chapter has not been updated in this project. In Chapter 1 and Chapter 11 the historic emissions have been updated but the projection and the text in this chapter is unchanged.

3.1 Methodology

The total emission of VOCs from the extraction of oil and gas is expressed in Equation 3.1.

$$Eq\,3.1 \qquad E_{total} = E_{extraction} + E_{GT} + E_{ship} + E_{pipeline} + E_{networks}$$

$E_{extraction}$ represents emissions from plants, which are used in connection with the offshore extraction of oil and gas and include emissions from venting, evaporation (fugitive loss) and flaring (refer to Equation 3.2).

$$Eq\,3.2 \qquad E_{extraction} = E_{venting} + E_{fugitive} + E_{flaring}$$

In Denmark, the venting of gas is considered to be very limited as the controlled emission is flared. $E_{venting}$ is, therefore, set to zero.

According to the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007), the total fugitive emission of VOC can be calculated by means of Equation 3.3:

$$Eq\,3.3 \qquad E_{VOC,fugitive} = 40.2 \cdot N_P + 1.1 \cdot 10^{-2} P_{gas} + 8.5 \cdot 10^{-6} \cdot P_{oil}$$

where N_P is the number of platforms, P_{gas} (10^6 Nm^3) is the production of gas and P_{oil} (10^6 tonnes) is the production of oil. If it can be considered that the VOC emitted consists of 75 % CH_4 and 25 % NMVOC, then the CH_4 and NMVOC emission can be calculated by means of Equations 3.4 and 3.5:

$$Eq\,3.4 \qquad E_{extraction,NMVOC} = E_{fugitive,NMVOC} + E_{flaring,NMVOC}$$
$$= 0.25(40.2 \cdot N_P + 1.1 \cdot 10^{-2} P_{gas} + 8.5 \cdot 10^{-6} \cdot P_{oil}) + F_P \cdot EMF_{flaring,NMVOC}$$

$$Eq\,3.5 \qquad E_{extraction,CH4} = E_{fugitive,CH4} + E_{flaring,CH4}$$
$$= 0.75(40.2 \cdot N_P + 1.1 \cdot 10^{-2} P_{gas} + 8.5 \cdot 10^{-6} \cdot P_{oil}) + F_P \cdot EMF_{flaring,CH4}$$

where $EMF_{flaring}$ is the emission factor for flaring.

The emission from gas treatment and storage can be arrived at via Equation 3.6:

$$Eq\ 3.6 \qquad E_{GT} = E_{GT,fugitive} + EMF_{flaring} \cdot F_{GT}$$

where $E_{GT,fugitive}$ represents the fugitive emissions, $EMF_{flaring}$ represents the emission factor for flaring and F_{GT} is the amount of gas flared.

The loading of ships with oil is carried out both offshore and onshore and the emission is calculated by means of Equation 3.7:

$$Eq\ 3.7 \qquad E_{ships} = EMF_{ships} \cdot L_{oil}$$

where EMF_{ships} is the emission factor for loading ships offshore and onshore and L_{oil} is the amount of oil loaded.

The emission of VOC from the transport of oil and gas in pipelines can be calculated by means of Equation 3.8:

$$Eq\ 3.8 \qquad E_{pipelines} = EMF_{pipeline,gas} \cdot T_{gas} + EMF_{pipeline,oil} \cdot T_{oil}$$

where T_{gas} and T_{oil} represent the amount of gas and oil transported, respectively, and $EMF_{pipeline,gas}$ and $EMF_{pipeline,olie}$ are the associated emission factors.

Emissions from the storage of crude oil can be calculated by means of Equation 3.9:

$$Equation\ 3.9 \qquad E_{\tan ks} = EMF_{\tan ks} \cdot T_{oil}$$

where EMF_{tanks} is the emission factor for storage of crude oil in tanks.

Emissions from the gas distribution network can be calculated by means of Equation 3.10:

$$Eq\ 3.10 \ E_{networks} = EMF_{network} \cdot C_{gas}$$

where C_{gas} is the amount of gas transported and $EMF_{network}$ is the emission factor for the transport of gas via the gas distribution network.

3.2 Activity data

3.2.1 Historic

Activity data used in the calculation of the emissions is provided in Table 3.1 and stems from either the Danish Energy Agency's publications (Danish Energy Agency, 2007a) or from information from the Danish Gas Technology Centre (Oertenblad, 2007) or from the Danish gas transmission company DONG's environmental accounts ('grønne regnskaber') (DONG, 2007). The emissions from flaring are calculated in Chapter 2, 'Stationary Combustion'.

Table 3.1 Activity data for 2006.

Activity	Symbol	Year 2006	Ref.
Number of platforms	N_p	50	Danish Energy Agency, 2007a
Gas produced (10^6Nm3)	P_{gas}	10 878	Danish Energy Agency, 2007a
Oil produced (10^3m3)	$P_{oil,vol}$	19 847	Danish Energy Agency, 2007a
Oil produced (10^3tonne)	P_{oil}	17 068	Danish Energy Agency, 2007a
Gas transported by pipeline (10^6Nm3)	T_{gas}	9 164	Danish Energy Agency, 2007a
Oil transported by pipeline (10^3m3)	T_{oil}	16 900	DONG, 2007
Oil transported by pipeline (10^3tonne)	T_{oil}	14 534	Danish Energy Agency, 2007a
Oil loaded (10^3m3)	$L_{oil\ off\text{-}shore}$	2 957	Danish Energy Agency, 2007a
Oil loaded (10^3tonne)	$L_{oil\ off\text{-}shore}$	2 543	Danish Energy Agency, 2007a
Oil loaded (10^3m3)	$L_{oil\ on\text{-}shore}$	13 100	DONG, 2007
Oil loaded (10^3tonne)	$L_{oil\ on\text{-}shore}$	11 266	DONG, 2007
Volume gas consumed (10^6Nm3)	C_{gas}	2 983	Oertenblad, 2007

Mass weight crude oil = 0.86 tonne pr m^3.

3.2.2 Prognosis

The prognosis for the production of oil and gas shown in Figure 3.1 presents a path where technological progress and new extraction possibilities are assumed (Danish Energy Agency, 2007b). A decline in the extraction of gas and to a less extent for oil from 2004 to 2030 is foreseen in the prognosis.

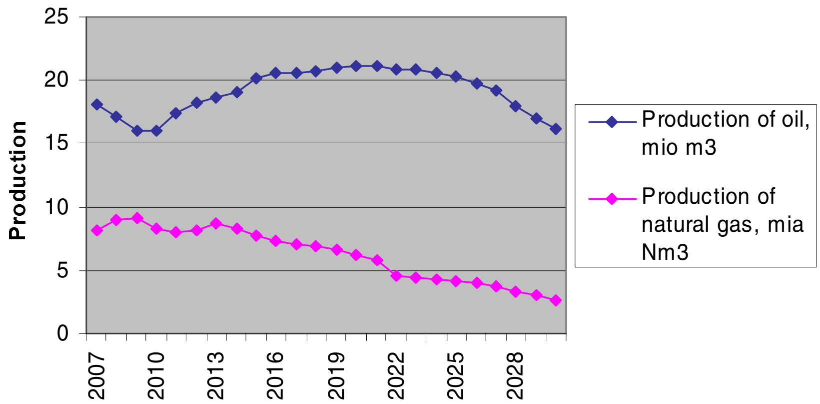

Figure 3.1 Prognosis for the production of oil and gas.

3.3 Emission factors

In the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007), the emission factors from different countries are provided. The Norwegian emission factors, which are also used in Norway's official emissions inventories (Flugsrud et al., 2000) have been selected for use in the projections (Table 3.2). The emissions from the storage of oil are stated in DONG's environmental accounts for 2006 (DONG, 2007) and the emission factor is calculated based on the amount of oil transported in pipelines.

Table 3.2 Emission factors for 2007-2009.

	CH_4	Unit	Ref.
Ships offshore	0.00005	Fraction of loaded	EMEP/CORINAIR, 2007
Ships onshore	0.000002	Fraction of loaded	EMEP/CORINAIR, 2007
Pipeline, gas 1)	14,57	Kg pr 103m3	Karll, 2003 & 2005; Oertenblad, 2006 & 2007
Oil tanks	112,43	Kg pr 103m3	DONG, 2007
Network 1)	23,23	Kg pr 106m3	Karll, 2003 & 2005; Oertenblad, 2006 & 2007

1) The emission factor is estimated as a mean of the emissions factors for a five year period (2002-2006).

According to the environment department of the local authority (Vejle Amt, 2005), stricter regulation of the emissions from oil tanks and onshore loading of ships is going to be introduced. The emission factors for these sources have therefore decreased by 99 % and 46 % from 2010. The emission factors from 2010 to 2030 are listed in Table 3.3.

Table 3.3 Emission factors for 2010-2030.

	CH_4	Unit	Ref.
Ships offshore	0.00005	Fraction of loaded	EMEP/CORINAIR, 2007
Ships onshore	0.00000108	Fraction of loaded	EMEP/CORINAIR, 2007; Vejle Amt, 2005
Pipeline, gas	14,57	Kg pr 103m3	Karll, 2003 & 2005; Oertenblad, 2006 & 2007
Oil tanks	1,12	Kg pr 103m3	DONG, 2007; Vejle Amt 2005
Network	23,23	Kg pr 106m3	Karll, 2003 & 2005; Oertenblad; 2006 & 2007

3.4 Emissions

The emissions for CH_4 are calculated based on the activity data in Table 3.1 and the emission factors in Tables 3.2 and 3.3.

Table 3.4 CH_4 emissions (tonnes).

Extraction:	2006	2030
Fugitive	1 589	1 244
Gas treatment and storage:		
Fugitive + Flaring	78	78
Pipelines:		
Gas	134	32
Oil	n.a.	n.a.
Network	69	17
Oil tanks	1 900	15
Total minus ships	3 770	1 386
Ships:		
Offshore	127	103
Onshore	23	10
Total	3 920	1 499

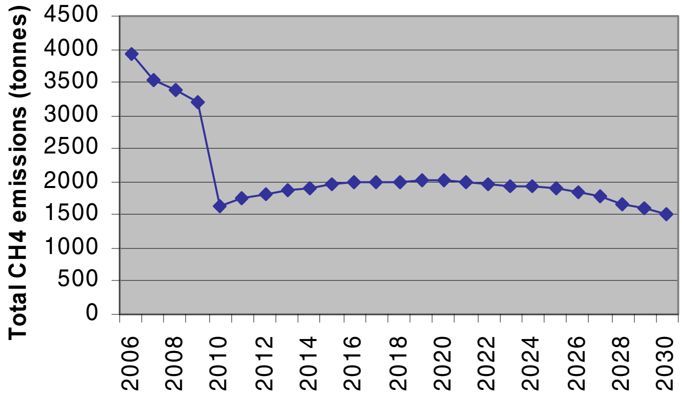

Figure 3.2 CH_4 emissions from oil and gas production.

Table 3.5 CH_4 emissions (ktonnes).

IPCC name	IPCC code	1990	1995	2000	2005	2007'	2010'	2015'	2020'	2025'
Fugitive emissions from oil	1B2a	1,54	2,26	3,48	4,44	3,30	2,12	1,72	1,81	1,72
Fugitive emissions from gas	1B2b	0,27	0,58	0,22	0,26	0,15	0,16	0,15	0,11	0,08
Total		1,80	2,84	3,70	4,70	3,45	2,28	1,87	1,92	1,80

Table 3.6 CH_4 emissions (ktonnes CO_2 equiv.).

IPCC name	IPCC code	1990	1995	2000	2005	2007'	2010'	2015'	2020'	2025'
Fugitive emissions from oil	1B2a	32	48	73	93	69	45	36	38	36
Fugitive emissions from gas	1B2b	6	12	5	5	3	3	3	2	2
Total		38	60	78	99	73	48	39	40	38

The decline in emissions reflects the expected environmental regulation in emissions from oil tanks and onshore loading of ships and decreasing extraction of oil and gas. It has been assumed that the number of platforms falls in line with the decline in extraction. The emission factors are assumed to be the same as those used in the historic inventories except for oil tanks and onshore loading of ships.

3.5 Model description

The model for the offshore industry is created in Microsoft Excel and the worksheets used in the model are collected in the 'Offshore model' The names and content of the tables are listed in Table 3.6.

Table 3.7 Tables in the 'Offshore model'.

Name	Content
Activity data	Historically data for 2000 to 2006 (Table 2.2.1) plus estimated activity rates for 2007 to 2030 based on data in table 'Projected production'.
Projected production	Projected production of oil and gas for 2007 to 2030.
EMF	Emission factors for CH_4 and NMVOC for all activities.
Emissions	Projected emissions for 2007 to 2030 based on data in tables 'Activity data' and 'Emission factors'.

Changing the data in the input data tables will automatically update the projected emissions.

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Vejle Amt, 2005: Personal communication.

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	Cement	04 06 12
		Quicklime and bricks	
		- Quicklime production	04 06 14
		- Brick production	04 06 14
		- Production of expanded clay products	04 06 14
		Glass and glass wool	
		- Production of packaging glass	04 06 13
		- Glass wool production	04 06 13
		Other processes	
		- Flue gas cleaning	04 06 18
		- Mineral wool production	04 06 18
		- Quicklime production for use in chemical processes	04 06 18
		Asphalt products	
		- Roof covering with asphalt products	04 06 10
		- Road surfacing with asphalt	04 06 11
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., 2010).

4.2 Projections

The results of projection of the GHG emission are presented in Table 4.2. The methodologies used are described below.

Aalborg Portland is the primary contributor to process emissions. No forecasts are available for consumption of cement. However, as for major energy consuming plants/sectors the Danish Energy Agency (2010) has included Aalborg Portland in the national energy forecasts. The energy consumption per produced amount of cement is assumed to be constant and therefore, the emission of CO_2 from the cement process is assumed to follow the energy consumption.

No forecasts are available for projecting the production of quicklime, bricks and expanded clay products to 2030. The emission from these products is therefore assumed to be constant at the 2008 level for the years 2009-2030.

No forecasts are available for the production of glass and glass wool to 2025. The emission from these processes is therefore assumed to be constant at the 2006 level.

'Other processes' includes CO_2 emissions from the use of lime for the production of mineral wool and for flue gas cleaning. The emissions from the production of mineral wool are assumed to be constant at the 2008 level over the period 2009-2030. The emission from flue gas cleaning is projected on the basis of expected future consumption of coal and waste in the energy sector (Danish Energy Agency 2009, 2010). Extrapolation factors are shown in Table 4.2.

Table 4.2 Extrapolation factors for estimation of CO_2 emissions from flue gas cleaning (based on projections by Danish Energy Agency (2010)).

	Coal PJ	Extrapol.	Waste PJ	Extrapol.
2008[1)]	162.3		37.9	
2009	163.9	1.01	35.2	0.93
2010	124.9	0.77	36.7	0.97
2011	113.7	0.70	37.1	0.98
2012	127.6	0.79	37.4	0.99
2013	102.7	0.63	39.6	1.04
2014	98.2	0.61	39.8	1.05
2015	115.5	0.71	41.3	1.09
2016	112.2	0.69	44.3	1.17
2017	118.4	0.73	43.5	1.15
2018	125.6	0.77	43.9	1.16
2019	121.9	0.75	45.6	1.20
2020	120.3	0.74	46.8	1.23
2021	121.8	0.75	47.1	1.24
2022	119.9	0.74	47.0	1.24
2023	120.2	0.74	46.9	1.24
2024	105.8	0.65	47.2	1.24
2025	104.5	0.64	47.8	1.26
2026	94.7	0.58	49.7	1.31
2027	92.5	0.57	49.7	1.31
2028	92.4	0.57	49.7	1.31
2029	85.9	0.53	49.6	1.31
2030	85.1	0.52	49.6	1.31

[1)] Energy Statistics 2008 (Danish Energy Agency, 2009).

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 emission is assumed to lie at the same level as in the period 1990-2003.

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.

No forecasts are available for consumption of lime for sugar refining and for consumption of lubricants and therefore the emission is assumed to be constant from 2009-2030 at 2008 level.

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

Year	2A Mineral Products	2B Chemical Industry	2C Metal Production	2D Food and drink	2G Lubricants	Total
1990	1069	0.80	28.4	4.45	49.7	1152
1991	1246	0.80	28.4	4.49	48.9	1329
1992	1366	0.80	28.4	4.14	48.1	1447
1993	1383	0.80	31.0	4.26	47.6	1466
1994	1406	0.80	33.5	4.36	46.9	1492
1995	1405	0.80	38.6	3.91	48.8	1497
1996	1512	1.45	35.2	3.80	48.9	1601
1997	1681	0.87	35.0	4.29	47.1	1768
1998	1615	0.56	42.2	4.90	44.9	1708
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	1321	2.40	0	2.67	34.0	1360
2010	1366	2.40	0	2.67	34.0	1405
2011	1399	2.40	0	2.67	34.0	1438
2012	1468	2.40	0	2.67	34.0	1507
2013	1531	2.40	0	2.67	34.0	1570
2014	1551	2.40	0	2.67	34.0	1590
2015	1529	2.40	0	2.67	34.0	1568
2016	1508	2.40	0	2.67	34.0	1547
2017	1503	2.40	0	2.67	34.0	1542
2018	1508	2.40	0	2.67	34.0	1548
2019	1527	2.40	0	2.67	34.0	1566
2020	1548	2.40	0	2.67	34.0	1587
2021	1580	2.40	0	2.67	34.0	1619
2022	1611	2.40	0	2.67	34.0	1650
2023	1641	2.40	0	2.67	34.0	1680
2024	1667	2.40	0	2.67	34.0	1706
2025	1704	2.40	0	2.67	34.0	1743
2026	1737	2.40	0	2.67	34.0	1776
2027	1777	2.40	0	2.67	34.0	1816
2028	1813	2.40	0	2.67	34.0	1853
2029	1838	2.40	0	2.67	34.0	1877
2030	1883	2.40	0	2.67	34.0	1922

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	2008	'2010' 2008-2012	'2015' 2013-2017	2020	2025	2030
2A	Mineral Products	1069	1405	1616	1544	1320	1375	1524	1548	1704	1883
2B	Chemical Industry	0.80	0.80	0.65	3.01	2.40	2.40	2.40	2.40	2.40	2.40
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	2.67	2.67	2.67	2.67	2.67	2.67
2G	Lubricants	49.7	48.8	39.7	37.6	34.0	34.0	34.0	34.0	34.0	34.0
	Total	1152	1497	1701	1604	1360	1414	1563	1587	1743	1922

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5 Solvents

This chapter has not been updated in this project. In Chapter 1 and Chapter 11 the historic emissions have been updated but the projection and the text in this chapter is unchanged. In addition the emission from use of N_2O as anaesthesia has been included. It is projected as the last inventory year (2008) kept constant to 2030.

5.1 Summary of method

Solvent use constitutes non-methane VOC (NMVOC) emissions of approximately 33 000 tonnes in 2006, which is one third of the total NMVOC emissions in Denmark. This amount represents 103 000 tonnes CO_2-equivalents, which constitutes 0.2 % of the total Danish CO_2 emissions (Illerup et al., 2007). Many different chemicals are categorized as solvents and thus used in various household products and industrial activities. The Danish NMVOC emission inventory for solvent use in industry and households is based on the detailed model as described in EMEP/CORINAIR (2004) and constitutes the following key issues:

- Defining the chemicals to be included.
- Quantifying use amounts for each chemical.
- Distributing use amounts to industry and household activities.
- Assigning emission factors to chemicals use.

The inventory includes chemicals from a gross list of 650 different chemicals and chemical groups (NAI, 2000). Use amounts for 427 NMVOCs are calculated from production, import and export figures derived from Statistics Denmark and of these, 44 NMVOCs constitute more than 95 % of the total use amount. The 44 NMVOCs are included in the solvent emissions inventory. Assignment of use amounts to industrial activities and households is made from SPIN (2007), a database comprising information on chemical consumption in industrial categories and product use categories. Emission factors have been obtained from the literature and personal communication with experts. Given the high complexity and uncertainty of data continuous refinements are being done and reported in the annual reports to EU and UN (e.g. Nielsen et al., 2010).

The N_2O emission from the use of anaesthesia is projected using the latest emission estimate from the emission inventory. The methodology is described in Nielsen et al. (2010).

5.2 Emission projections

Emission projections have been made for four industrial sectors: "Auto paint and repair", "Plastic industry", "Graphic industry" and "Lacquer and paint industry". Together they comprise approximately 28 % of the total NMVOC emission in 2006, and are thus suitable indicators for the total Danish NMVOC emissions trends. Projections for all other industrial sectors and for households are based on linear projections of historical 1995 – 2006 emissions.

Production and use of VOC containing products are regulated by two national directives "Directive no 350 on Limitation of Emissions of Volatile Organic Compounds from use of Organic Solvents in Certain Activities" aka VOC-directive, and "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. The directives supplement each other, as the VOC-directive regulates activities with VOC consumption above a certain limit value, and Directive 1049 regulates activities with VOC consumption below the limit value.

Not all activities in the four sectors 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. Projections on, e.g. solvent use for processing plastic are based on expert judgements on ongoing or planned emission reducing measures.

5.2.1 Auto paint and repair

Projections are based on fulfilment of NMVOC limit values in auto paint and lacquer products stated in the VOC directive and Directive 1049. For this sector the limit values are identical in the two directives and are also reached by fulfilling a reduction program outlined in the VOC-directive:

$$M = P * R = P * T * F \qquad (3)$$

Where M is the target emission to be reached 31 October 2007, P is the ratio between target emission and reference emission, T is the dry mass of surface coating, lacquers, adhesives and paints used in a year, F is the ratio between NMVOC emission and dry matter (T). R (= T * F) is the reference emission and represents the annual emission on 31 October 2007 that would occur if emission reduction measures had not been implemented.

P is found from the VOC directive to be 0.4, the reference emission R is found from linear extrapolation of the 1995 – 2006 inventory data to be 3.23 ktonnes per year. It is estimated that a third of the solvent use is in paints and lacquers and the remaining two thirds are therefore not regulated by the directives:

31.10.2007 emission = 3.23 * (0.67 + 0.33 * 0.4) = 2.59 ktonnes per year

Projections to 2010 and 2020 are based on linear extrapolation of 1995 – 2006 emissions and subtracted the 2007 reductions:

2010 emission = 2.90 – 3.23 * 0.33 * (1 – 0.4) = 2.26 ktonnes per year

2020 emission = 1.80 – 3.23 * 0.33 * (1 – 0.4) = 1.16 ktonnes per year

5.2.2 Graphic industry

Graphic industry covers heat set-rotation, magazine photogravure, other photogravure, flexography, serigraphy, lamination and lacquering. The

VOC directive regulates activities with VOC consumption above 20 tonnes per year. Activities with VOC consumption below 20 tonnes per year are, however, not regulated by Directive 1049, as this covers paints and lacquers for buildings only.

Larger industries (use > 20 tonnes per year) use catalytic and thermal combustion of solvents, which reduces NMVOC emission below limit values in the VOC directive. An emission factor of 5 % is estimated for emissions from solvent use in larger industries. Conservative emission projections are made based on extrapolation of 2006 emissions. It is assumed that NMVOC use is divided equally between smaller (< 20 tonnes per year) and larger (use > 20 tonnes per year) industries, which yields:

31.10 2007 emission = 2010 emission = 2030 emission =

1.51 * (0.5 * 0.05 + 0.5) = 0.79 ktonnes peryear

5.2.3 Lacquer and paint industry

This industry covers processing of surface coating, lacquers, adhesives and paints, e.g. through mixing of pigments, binders and adhesives with organic solvents and dissolving, dispersing, adjustment of viscosity, toning and tapping of the final products.

Emissions are mainly diffuse and are - in the emission inventory - estimated to be approximately 1 % of the NMVOC content in the products (Møller, 1995). The emission limit values are 3 % of the NMVOC content for activities with NMVOC consumption between 100 and 1000 tonnes per year, and 5 % of the NMVOC content for activities with NMVOC consumption > 1000 tonnes per year, according to the VOC directive.

For the NMVOC consumption below 100 tonnes per year, limit values for NMVOC content in water-based and solvent-based paints, lacquers, primers and other surface coatings are stated in Directive 1049 for fulfilment in 2007 and 2010, respectively. These limit values are compared to estimates of NMVOC content in water and solvent based products, derived from Møller (1995).

Directive 1049 limit values for water-based paints and lacquers (19 % of the industry's NMVOC consumption) comply with the actual content, which is also the case for water-based wood preservation (2 % of NMVOC consumption) and part of the solvent-based wood preservation (32 % of the NMVOC consumption). For solvent-based paints and lacquers (34 % of the NMVOC consumption) the limit values are exceeded, which is also the case for part of the solvent-based wood preservation (32 % of the NMVOC consumption). The solvent content has decreased in paints and lacquers since 1995, which increases the amount of products that fulfil the limit values.

Linear extrapolation of 1995 – 2006 inventory data is used for projecting emissions:

31.10 2007 emission = 0.222 ktonnes per year.

2010 emission = 0.226 ktonnes per year.

2020 emission = 0.241 ktonnes per year.

5.2.4 Plastic industry

The plastic industry covers three main activities; production of expanded polystyrene products (EPS-branch), production of fibreglass-reinforced polyester products (composite-branch) and production of polyurethane products (PUR-branch).

Production of plastic materials does not take place in Denmark, only manufacturing and processing of plastic containing products are relevant. E.g. polystyrene products are manufactured from imported polystyrene pellets. Apart from small amounts of solvent used in surface treatment of plastic products the plastic industry is not regulated by the VOC directive or Directive 1049.

A number of emission reducing measures are being implemented at the moment; 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. It is not possible for the industry to predict the effects of these measures, therefore a static and conservative estimate with constant emissions, at 2006 level, are estimated in 2007, 2010 and 2030.

5.3 Summary for solvents

Table 5.1 Summary of projected Danish NMVOC and CO_2 emissions for four selected sectors and total emissions (ktonnes/year).

	Auto paint and repair[1)]	Graphic industry[2)]	Lacquer and paint industry[3)]	Plastic industry[4)]	Total NMVOC emissions[5)]	Total CO_2 emissions[6)]
31.10.2007	2.59	0.79	0.222	3.87	28.8	89.8
2010	2.26	0.79	0.226	3.87	25.5	79.5
2030	1.16	0.79	0.241	3.87	25.5	79.5

[1)] Regulated by VOC-directive and Directive 1049

[2)] Not covered by B1049. Reductions are estimated from catalytic and thermal combustion of solvent in larger plants

[3)] Linear projection

[4)] 2006 emissions are assumed in 2007, 2010 and 2030. Static and conservative estimate

[5)] Other sectors and industries from 2007 to 2010 are based on linear projections of 1995 – 2006 inventory data. Constant 2010 emissions are projected to 2030.

[6)] A conversion factor of 0.85*3.6667 kg CO_2/kg NMVOC is used.

Differentiation in CRF categories is based on emissions of single chemicals and not on emissions from industrial sectors and households. The projected emissions from the four investigated sectors are therefore not differentiated in CRF sectors in the present inventory. The relative distribution in CRF sectors of the last historical year (2006) are used for the projected emissions.

The projected emissions in Table 5.2 and Figure 5.1 shows historical (1995-2006) and projected (2007-2030) CO_2 emissions of 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).

Table 5.2 shows the Danish NMVOC emissions for UNFCCC source categories. 1995 – 2006. Consumed amounts of NMVOCs are from StatBank Denmark (2007), the emission factors are from various sources, e.g. Rypdal (1994) and distribution on source categories are from SPIN use categories (SPIN, 2007). 2007 – 2025 are projections.

Table 5.2 Danish NMVOC emissions for UNFCCC source categories.

	1990	1995	2000	2005	2007	2010	2015	2020	2025
Paint application (3A)	60.71	50.15	48.38	40.81	36.46	32.28	32.28	32.28	32.28
Degreasing and dry cleaning (3B)	25.41	21.39	20.57	17	15.66	13.87	13.87	13.87	13.87
Chemical products, manufacturing and processing (3C)	10.14	11.07	8.82	10.32	7.746	6.859	6.859	6.859	6.859
Other (3D)	51.84	56.29	34.87	35.06	29.89	26.47	26.47	26.47	26.47

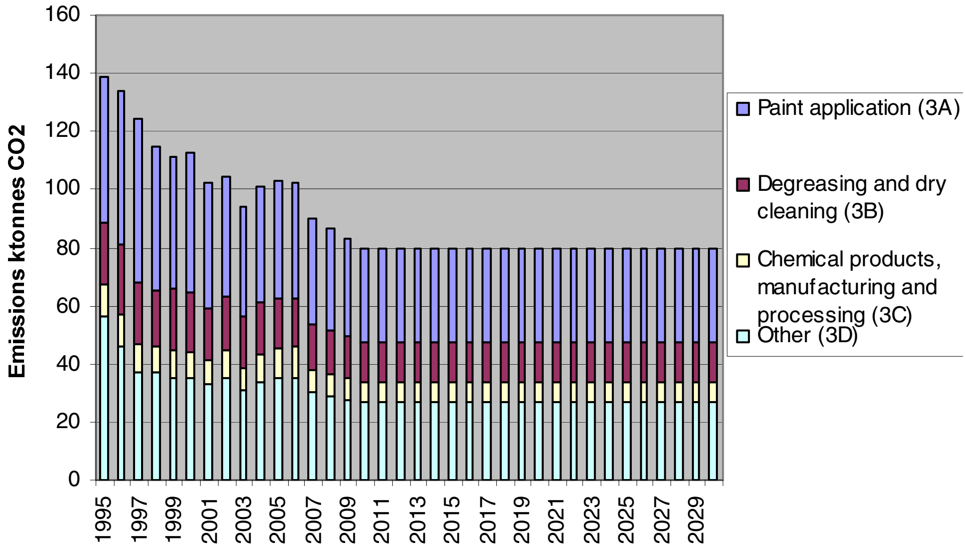

Figure 5.1 Danish NMVOC emissions for 1995 – 2030. 2007 – 2030 are projections.

There is a 27 % decrease in total VOC emissions from 1995 to 2006. Of the 26 industries and sectors nine show an increase. Households, construction, plastic industry, industrial mass produced products and auto paint and repair are the largest sources to the Danish VOC emissions from solvent use, constituting 13 %, 13 %, 12 %, 11 % and 10 % of the total 2006 CO_2 emissions, respectively. Household use and the plastic industry show the largest increase relative to the total emissions. Household emissions are dominated by propane and butane, which are used as aerosols in spray cans, primarily in cosmetics. The increase in emissions from household use is mainly from increased use of ethanol glycerol and naphthalene. The main solvents used in the plastic industry are pentane, methanol and acetone and the emission increase originate mainly from increased use of pentane and methanol. Industrial mass produced products and graphics industry show the largest decreases relative to the total emissions. The decrease for industrial mass produced products originate from reduced use of turpentine and propylalcohol and the decrease in graphics industry is from reduced use of propylalcohol.

Overall, the most abundantly used solvents are methanol, propylalcohol and turpentine, or white spirit defined as a mixture of stoddard solvent and solvent naphtha. Methanol is primarily used as intermediate (monomer), solvent in thinners, degreasers and as disinfecting and conserving agent. Propylalcohol is used as flux agents for soldering, as solvent and thinner and as windscreen washing agent. Turpentine is used as thinners for paints, lacquers and adhesives.

References

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6 Transport

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 5.1 (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 5.2 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. (2010).

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 1999-2008 and by using appropriate assumptions the mileage has been back-casted to 1985 and forecasted to 2030.

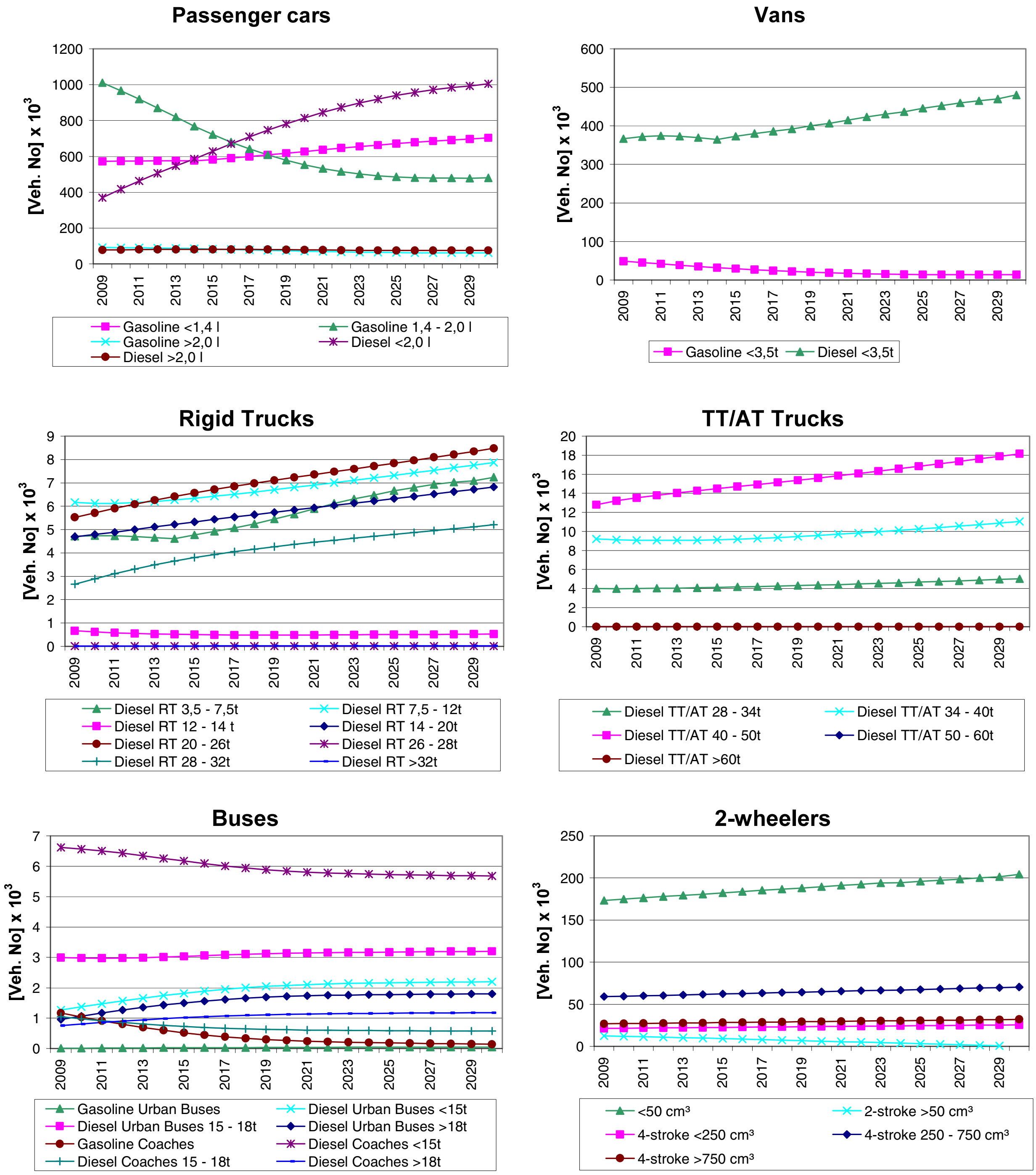

Figure 5.1 Number of vehicles in sub-classes from 2009-2030.

The vehicle numbers per sub-class are shown in Figure 5.1. The engine size differentiation is associated with some uncertainty.

The vehicle numbers are summed up in layers for each year (Figure 5.2) 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 2009-2030. The trends in vehicle numbers per EU layer are also shown in Figure 5.2 for the 2009-2030 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.

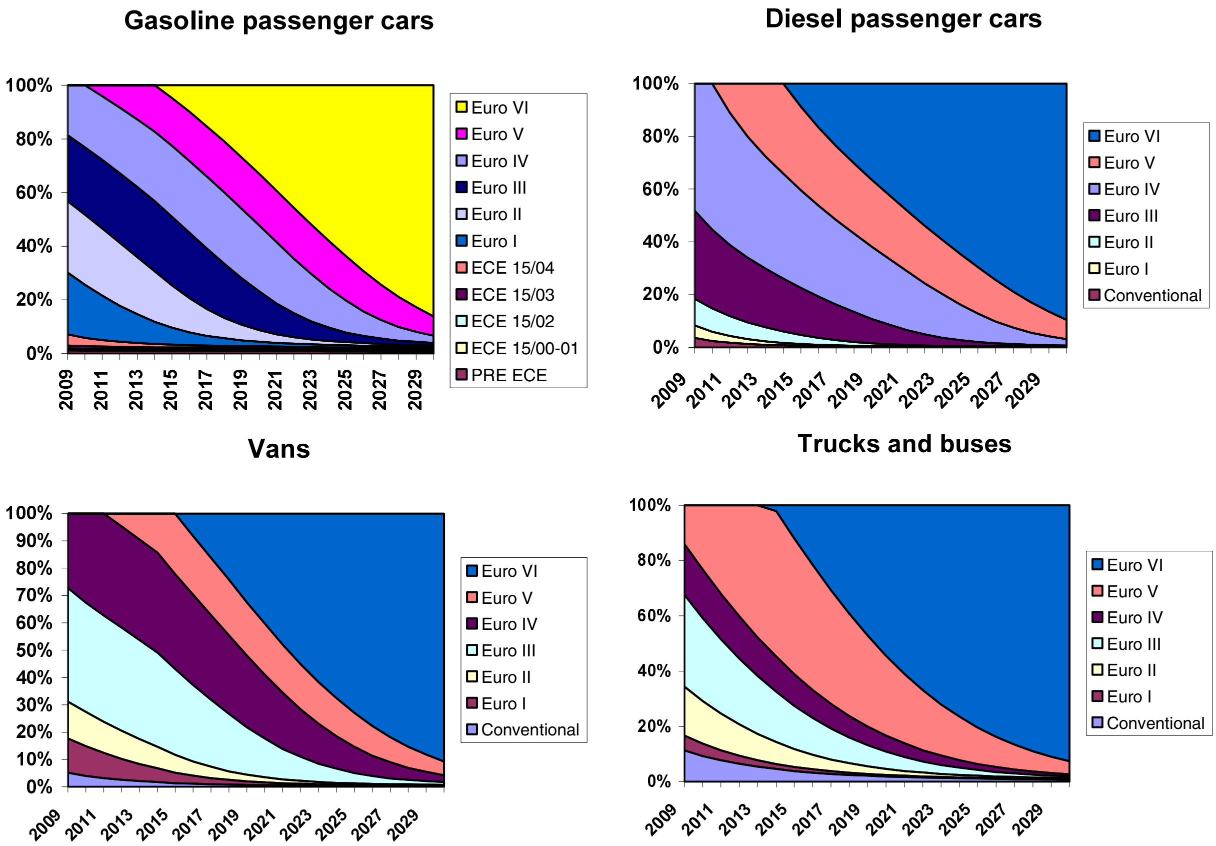

Figure 5.2 Layer distribution of vehicle numbers per vehicle type in 2009-2030.

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 overall fleet average. Only the fleet average is regulated, so manufacturers will still be able to make vehicles with emissions above the limit value curve provided these are balanced by other vehicles which are below the curve.
- Vehicles affected: the vehicles affected by the legislation are vans, which account for around 12 % of the market for light-duty vehicles. This includes vehicles used to carry goods weighing up to 3.5 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.

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 2009-2030. 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 2001-2008, 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 statistics (DEA, 2009).

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 (2010) 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.

National sea transport

A new methodology is used to estimate the fuel consumption figures for national sea transport based on fleet activity estimates for regional ferries, local ferries and other national sea transport (Winther, 2008a). The estimated fuel totals per fuel type for national sea transport replace the fuel sales projections from DEA (2010).

Following this, for fisheries and industry (stationary sources) the updated fuel consumption time-series for national sea transport lead, in turn, to changes in the fuel activity data for fisheries (gas oil) and industry (heavy fuel oil), so the national energy balance can remain unchanged.

Table 5.5 lists the most important domestic ferry routes in Denmark in the period 1990-2008. For these ferry routes the following detailed traffic and technical data have been gathered: Ferry name, year of service, engine size (MCR), engine type, fuel type, average load factor, auxiliary engine size and sailing time (single trip). The same data have also been gathered for 2006 and 2007 for use in the present project, in the case of Mols-Linien (Sjællands Odde-Ebeltoft, Sjællands Odde-Århus, Kalundborg-Århus; Hansen et al., 2004; Wismann, 1999; PHP, 1996; Kristensen, 2008; Hjortberg, 2008) and Bornholmstrafikken (Køge-Rønne). The ferry specific data for 2007 are used for 2008 also. For the years 2008+ the sailing activities are assumed to be the same as in 2008.

Please refer to Winther (2008a) for detailed information about the number of round trips per ferry route, different ferry specific technical and operational data, as well as issues regarding the balance between fleet activity based fuel consumption estimates and projected fuel sales figures.

Table 5.5 Ferry routes comprised in the present project.

Ferry service	Service period
Halsskov-Knudshoved	1990-1999
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 (2010). 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 fisheries, the calculation methodology described by Winther (2008a) remains fuel based. However, the input fuel data differ from the fuel sales figures previously used. The changes are the result of further data processing of the DEA reported gas oil sales for national sea transport and fisheries, prior to inventory input.

For all other mobile sectors, fuel consumption figures are given in Annex 5.2 for the years 2009-2030 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	CO	VOC	NO_X	VOC+NO_X	PM	Diesel machinery			Tractors	
size [kW]						EU	Implement. date		EU	Implement.
	[g pr kWh]					directive	Transient	Constant	directive	date
Stage I										
37<=P<75	6.5	1.3	9.2	-	0.85	97/68	1/4 1999	-	2000/25	1/7 2001
Stage II										
130<=P<560	3.5	1	6	-	0.2	97/68	1/1 2002	1/1 2007	2000/25	1/7 2002
75<=P<130	5	1	6	-	0.3		1/1 2003	1/1 2007		1/7 2003
37<=P<75	5	1.3	7	-	0.4		1/1 2004	1/1 2007		1/1 2004
18<=P<37	5.5	1.5	8	-	0.8		1/1 2001	1/1 2007		1/1 2002
Stage IIIA										
130<=P<560	3.5	-	-	4	0.2	2004/26	1/1 2006	1/1 2011	2005/13	1/1 2006
75<=P<130	5	-	-	4	0.3		1/1 2007	1/1 2011		1/1 2007
37<=P<75	5	-	-	4.7	0.4		1/1 2008	1/1 2012		1/1 2008
19<=P<37	5.5	-	-	7.5	0.6		1/1 2007	1/1 2011		1/1 2007
Stage IIIB										
130<=P<560	3.5	0.19	2	-	0.025	2004/26	1/1 2011	-	2005/13	1/1 2011
75<=P<130	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
56<=P<75	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
37<=P<56	5	-	-	4.7	0.025		1/1 2013	-		1/1 2013
Stage IV										
130<=P<560	3.5	0.19	0.4	-	0.025	2004/26	1/1 2014		2005/13	1/1 2014
56<=P<130	5	0.19	0.4	-	0.025		1/10 2014			1/10 2014

Table 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 5.8. 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 5.10.

Table 5.10 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[2]: 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 3.31.

Table 3.31 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.

In relation to the sulphur content in heavy fuel and marine gas oil used by ship engines, Table 3.32 shows the current legislation in force.

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

Table 3.32 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, 2009) 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 2009-2030.

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 (2010), 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 5.11 for all mobile sources in Denmark. The ‘2010’ and ‘2015’ results are the average figures for the years 2008-2012 and 2013-2017, respectively.

Table 6.11 Summary table of fuel consumption and emissions for mobile sources in Denmark.

		1990	1995	2000	2005	2008	2010	"2010"	2015	"2015"	2020	2025	2030
Energy	Industry - Other (1A2f)	11.5	11.6	12.0	13.0	15.2	15.3	15.4	15.6	15.6	15.5	15.5	15.5
	Civil Aviation (1A3a)	3.4	2.8	2.1	1.9	2.3	2.3	2.3	2.5	2.5	2.8	3.0	2.9
	Road (1A3b)	126.2	144.1	152.5	166.1	176.2	167.9	171.3	175.5	175.3	175.8	182.1	191.7
	Railways (1A3c)	4.0	4.1	3.1	3.1	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
	Navigation (1A3d)	9.4	10.2	6.4	6.3	6.1	6.1	6.1	6.0	6.0	6.0	6.0	5.9
	Residential (1A4b)	1.5	1.6	1.8	3.0	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2
	Ag./for./fish. (1A4c)	25.7	23.4	21.8	21.3	22.9	23.8	23.8	25.4	25.4	26.7	27.9	29.1
	Military (1A5)	1.6	3.4	1.5	3.7	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Navigation int. (1A3d)	40.2	66.3	56.0	34.5	40.7	40.8	40.7	40.8	40.8	40.8	40.8	40.8
	Civil Aviation int. (1A3a)	24.1	25.9	32.6	35.8	36.7	32.8	34.2	37.2	37.5	42.6	44.1	41.1
CO_2	Industry - Other (1A2f)	842	848	879	950	1119	1126	1126	1143	1141	1136	1139	1134
	Civil Aviation (1A3a)	243	199	154	135	164	167	168	182	183	204	214	210
	Road (1A3b)	9275	10585	11202	12214	12948	12267	12346	12176	12162	12202	12640	13312
	Railways (1A3c)	297	303	228	232	237	237	237	237	237	237	237	237
	Navigation (1A3d)	714	766	476	471	453	452	452	450	450	450	450	436
	Residential (1A4b)	113	118	129	220	239	236	236	233	233	233	233	233
	Ag./for./fish. (1A4c)	1899	1728	1615	1577	1697	1764	1759	1882	1882	1979	2064	2150
	Military (1A5)	119	252	111	271	108	107	107	105	105	105	105	105
	Navigation int. (1A3d)	3087	5061	4279	2636	3118	3126	3124	3126	3126	3126	3126	3126
	Civil Aviation int. (1A3a)	1736	1867	2350	2574	2642	2358	2462	2681	2699	3066	3173	2962
CH_4	Industry - Other (1A2f)	60	53	50	45	41	39	39	35	35	33	32	32
	Civil Aviation (1A3a)	7	7	5	7	6	4	4	4	4	5	5	5
	Road (1A3b)	2623	2374	1865	1393	1046	732	778	506	508	361	291	250
	Railways (1A3c)	12	13	10	9	8	4	5	2	2	0	0	0
	Navigation (1A3d)	31	35	30	32	32	32	32	31	31	31	31	31
	Residential (1A4b)	150	136	137	219	240	225	226	207	209	207	207	207
	Ag./for./fish. (1A4c)	139	106	88	86	91	88	88	82	82	80	81	81
	Military (1A5)	5	18	6	13	5	3	4	3	3	2	2	2
	Navigation int. (1A3d)	65	110	97	62	75	77	77	79	79	81	83	83
	Civil Aviation int. (1A3a)	31	35	42	49	51	43	45	49	49	56	58	54
N_2O	Industry - Other (1A2f)	34	35	37	40	47	48	48	49	49	49	49	49
	Civil Aviation (1A3a)	10	10	8	8	9	6	7	7	7	7	8	8
	Road (1A3b)	313	416	447	413	405	388	392	373	374	365	382	408
	Railways (1A3c)	8	8	6	6	7	7	7	7	7	7	7	7
	Navigation (1A3d)	43	46	27	27	26	26	26	26	26	26	26	25
	Residential (1A4b)	2	2	2	3	4	4	4	4	4	4	4	4
	Ag./for./fish. (1A4c)	87	81	78	76	81	84	84	90	90	95	100	105
	Military (1A5)	4	7	3	9	4	4	4	4	4	4	4	4
	Navigation int. (1A3d)	194	318	269	166	196	197	196	197	197	197	197	197
	Civil Aviation int. (1A3a)	59	64	82	89	90	128	123	146	147	167	173	161
GHG-eq.	Industry - Other (1A2f)	853	860	892	963	1134	1141	1142	1159	1157	1152	1155	1150
	Civil Aviation (1A3a)	246	202	157	137	167	169	170	184	185	207	217	213
	Road (1A3b)	9427	10764	11380	12371	13096	12403	12484	12303	12288	12322	12764	13444
	Railways (1A3c)	300	306	230	234	239	239	239	239	239	239	239	239
	Navigation (1A3d)	728	781	485	480	462	461	461	458	458	458	458	444
	Residential (1A4b)	116	121	133	226	245	242	242	239	239	238	238	238
	Ag./for./fish. (1A4c)	1929	1755	1641	1603	1724	1792	1787	1911	1912	2010	2096	2184
	Military (1A5)	120	255	112	274	109	109	108	106	106	106	106	106
	Navigation int. (1A3d)	3149	5162	4365	2689	3180	3188	3187	3188	3188	3189	3189	3189
	Civil Aviation int. (1A3a)	1755	1888	2376	2603	2671	2399	2501	2728	2745	3119	3227	3013

6.3.1 Road transport

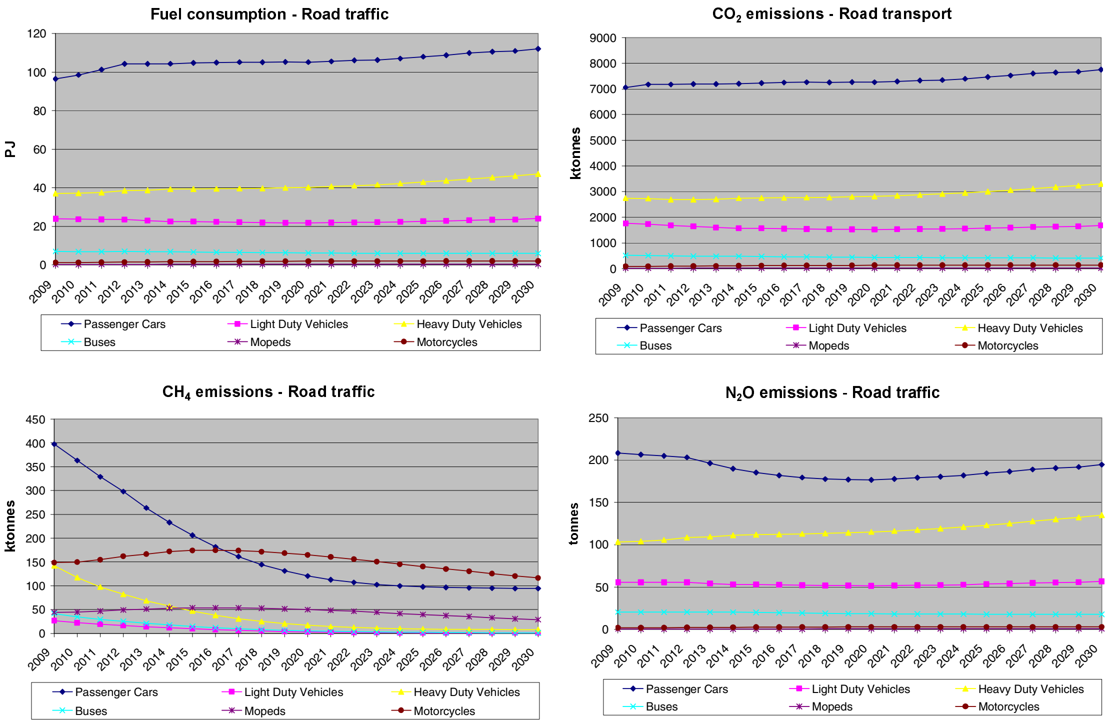

Figure 6.3 Fuel consumption, CO_2, CH_4 and N_2O emissions from 2009-2030 for road traffic.

The total fuel consumption for road traffic increases by 15 % from 2009 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 (2010) 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 2009-2030.

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 69 % from 2009 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

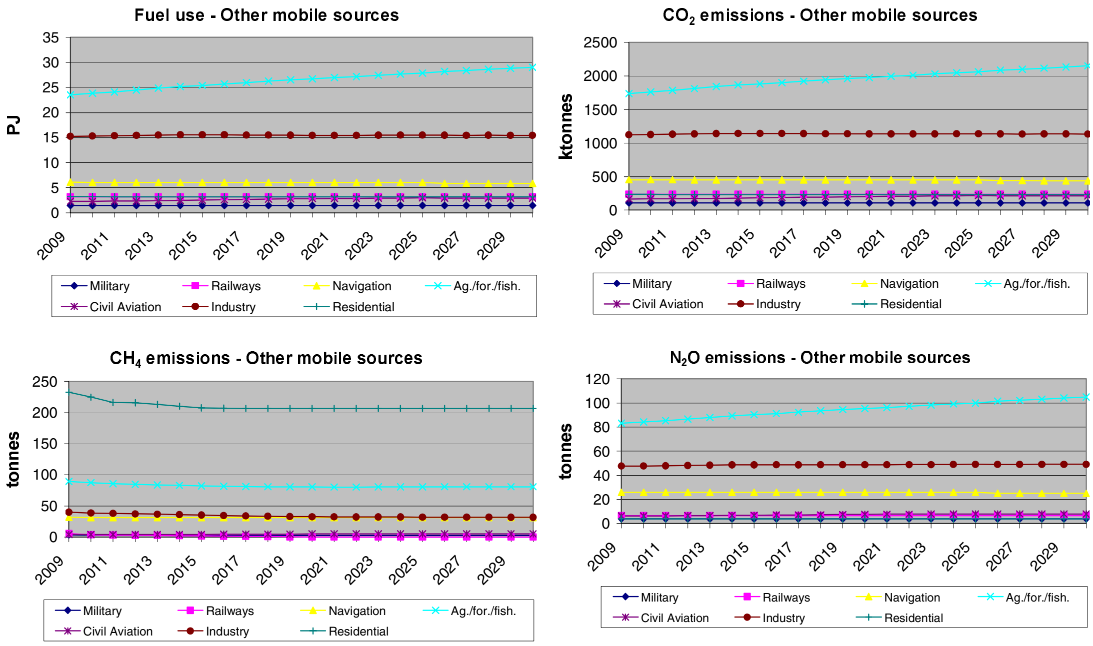

Figure 5.4 Fuel consumption, CO_2, CH_4 and N_2O emissions from 2009-2030 for other mobile sources.

For other mobile sources the fuel consumption for Agriculture/-forestry/fisheries (1A4c) is expected to increase by 24 % from 2009 to 2030, due to expected increases in the order of 22 % and 28 % for fishery and agricultural machinery, respectively, in the same time periods (not shown). For air traffic, the DEA energy projections assume a growth rate for domestic flights corresponding to a fuel consumption increase of 21 % from 2009 to 2030. The marginal fuel consumption decrease for Industry (1A2f), Residential (1A4b) and Navigation (1A3d) is due to a gradual phase out of older and less fuel efficient technology.

Agriculture/forestry/fisheries (1A4c) is the most important source of N_2O emissionns, followed by Industry (1A2f) and Navigation (1A3d). The emission reduction for the latter sector is due to the gradual shift from 2-stroke to 4-stroke gasoline engines in recreational craft (also visible for CH_4). 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)

This chapter has not been updated in this project. In Chapter 1 and Chapter 11 the historic emissions have been updated but the projection and the text in this chapter is unchanged.

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). In this connection, projections to 2020 are also prepared. Annual reports that contain both consumption and emission data are available.

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. Neither do the projections take the cease of the Danish bans on e.g. refrigeration equipment in 2013 into account. In the emission inventories for 2004, 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 dominates 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-equiv.
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-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-227ea
HFC mixtures						
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, 2008. 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 (2025)

Data is available for historic values for F-gas emissions for the period 1993-2006, as well as projected values for the period 2005-2020 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 2008 report prepared for DEPA (DEPA, 2008). 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. Small deviations between the data in Table 6.2 and that reported for 1993-2006 have been explained above (the latest reported data are http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories/Submission_UNFCCC/colsasntw/envsasn6g)

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 the projection after 2020, the total projected emission for 2020 is retained.

Table 7.1 Total F-gas emissions in CO_2-equiv. (1 000 tonnes). Historic data: 1993-2006. Projections: 2007-2020.

Year	Sum HFCs	PFCs	SF_6	Total F-gases
1993	93.9	0.0	101.2	195.1
1994	134.5	0.1	122.1	256.6
1995	217.7	0.5	107.3	325.6
1996	329.3	1.7	61.0	391.9
1997	323.7	4.1	73.1	400.9
1998	411.0	9.1	59.4	479.5
1999	502.6	12.5	65.4	580.5
2000	604.1	17.9	59.2	681.2
2001	646.4	22.1	30.4	698.9
2002	671.2	22.2	25.5	718.8
2003	694.4	19.3	31.9	745.6
2004	747.8	15.9	33.1	796.8
2005	803.9	13.9	21.8	839.5
2006	833.6	15.7	36.0	885.3
2007	844.2	13.9	35.5	893.6
2008	846.7	12.4	35.7	894.7
2009	829.7	11.2	35.9	876.8
2010	804.4	10.3	36.1	850.8
2011	755.7	9.6	69.3	834.6
2012	692.1	8.9	115.4	816.4
2013	645.9	8.3	125.4	779.7
2014	563.3	7.8	137.9	709.0
2015	487.9	7.4	123.2	618.6
2016	404.7	7.0	95.5	507.2
2017	347.6	6.6	80.6	434.9
2018	267.5	6.3	110.6	384.4
2019	225.0	6.0	79.8	310.9
2020	151.8	5.8	59.3	216.9

Table 7.2 Total emission of F-gases in CO_2-eqv. (1 000 tonnes). Historic data: 1993-2006. Projections: 2007-2020. After 2020, the emission value for 2020 is retained.

CRF-sector	Year	1995	2000	2005	2007	2010	2015	2020	2025
	Note	(1)				(2)	(3)		
2. Industrial Processes.									
F. Consumption of Halocarboner and SF_6		325.6	681.2	839.5	893.6	854.7	609.9	216.9	216.9

Note:

(1) Relevant data is not available for 1990; 1995 can be selected in the KP for F-gases as the base year.

(2) 5-year average: 2008-2012.

(3) 5-year average: 2013-2017.

In Figure 7.1, the data from Table 7.2 are illustrated. The apparent increase within historic data for the total F-gas emission runs from 1995 (1993) to the most recent historic inventory for 2006. 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 fall towards the end of the period; this path reflects the expected emission from the destruction of double-glazing in which SF_6 is used.

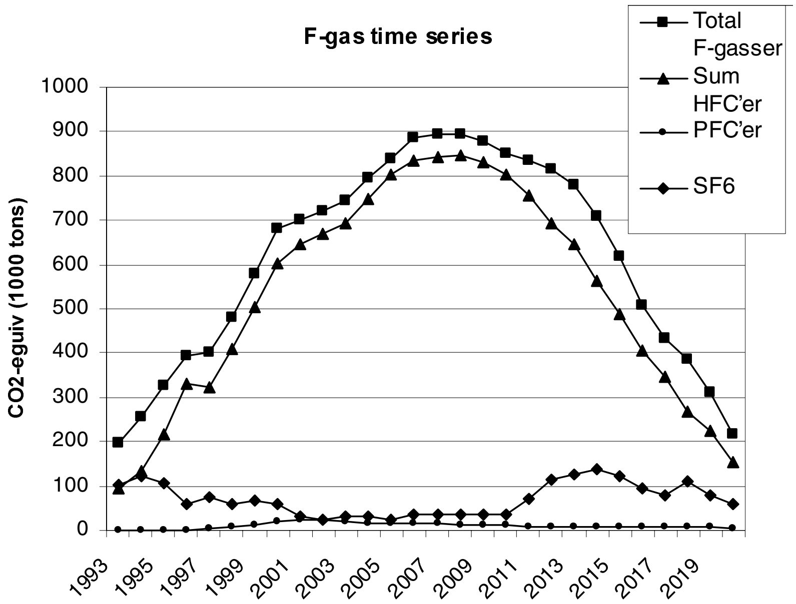

Figure 7.1 Time-series for F-gas emissions, divided into HFCs, PFCs and SF_6.

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8 Agriculture

The emission of GHGs from the agricultural sector includes the emission of CH_4 and N_2O. The emission of CO_2 from agriculture is not included in this projection as it is reported under forestry and land-use change (LULUCF – Land Use, Land Use Change and Forestry). The projection comprises an assessment of the GHG emissions from the agricultural sector to 2030.

This chapter has not been updated in the current project. Therefore, the data presented do not necessarily correspond to the data presented in the summary and conclusions. The methodology used is the same as presented in this chapter.

8.1 Projection of agricultural greenhouse gas emissions

Assessment of future GHG emissions from the agricultural sector is regularly updated in line with actual developments and new scientific knowledge. The present projection is similar to the latest basic projection for GHGs published in 2007 (Illerup et al., 2007), except that the historic emission from 1990 to 2006 has been updated in accordance with the latest official reporting from Denmark.

The following measures are included in the present projection. The ammonia action plan, improvements in feed efficiency, the effects of implementation of the Plan For the Aquatic Environment III (VMPIII), the EU agricultural reform and expected emission reducing technologies.

In the period from 1990 to 2006, the emission of GHGs declined from 13 044 ktonnes CO_2 equivalents to 9 605 ktonnes CO_2 equivalents.

Until 2010 a slightly increase is expected in the GHG emission from agriculture to 9 930 ktonnes CO_2 equivalents.

A slight decrease is expected in 2025 bringing down the total emission to 9 360 ktonnes CO_2 equivalents. This means that in the period from 2006 to 2025 emissions are expected to decrease by 2.6 % – see Table 8.1.

CH_4 emissions will increase slightly in the near future due to the fact the number of dairy cows in the future is not reduced as previously assumed. The main reason is the currently planned increase in the Danish milk quota, which in the short term will not reduce the number of cows. In the long term a steady milk production is expected leading to a decrease in the CH_4. The change in the number of cattle also contributes to changes in the N_2O emission, but the reduction in the emission from the leaching of nitrogen (N-leaching) and artificial fertiliser is of greater importance. It is expected that N-leaching will be reduced as a result of initiatives implemented in connection with the Danish VMPIII, where it has been decided that the amount of leached N shall be reduced with a minimum of 13 % by 2015 compared to 2003. Artificial fertiliser use is expected to fall, partly due to the decrease in land area under agricultural cultivation and partly due to improved utilisation of nitrogen in animal manure.

Measures in the form of technologies to reduce ammonia emissions in the stable and expansion of biogas plant do not contribute to significant changes in the total GHG emission from the agricultural sector. Both the GHG emission related to the emission of ammonia and the emission reductions from biogas production are currently relatively minor emission sources, contributing to the total GHG emission with approx. 4 %, in total. The current Danish energy plan plans to more than double the amount of animal manure treated in biogas plants. It is assumed that this target will be reached in 2020.

The overall emission figures is shown in Table 8.1

Table 8.1 Projected greenhouse gas emission from the different sectors until 2025.

	CRF category	*Source*	*1990*	*2000*	*2006*	*2010*	*2020*	*2025*
CH_4, Gg	4A – Enteric Fermentation	Enteric fermentation	155.19	136.28	123.93	130.37	117.23	118.96
	4B - Manure Management	Manure Management (incl. reduction from biogas)	35.77	45.44	49.63	50.26	60.61	58.45
		Total	190.96	181.73	173.56	180.63	177.84	177.42
N_2O, Gg	4B- Manure Management	Manure Management (incl. reduction from biogas)	2.21	1.94	1.67	1.88	1.65	1.65
	4D.1 – Direct Soil Emissions	Mineral fertilizer	7.69	4.83	3.68	3.74	3.17	3.17
		Animal manure applied to soils	3.51	3.40	3.43	3.77	3.86	3.88
		N-fixing crops	0.87	0.75	0.68	0.68	0.68	0.68
		Crop residue	1.17	1.09	1.06	1.04	1.00	1.00
		Histosoils	0.38	0.36	0.37	0.35	0.35	0.35
	4D.2 – Animal Production	Pasture	1.01	0.99	0.90	0.89	0.79	0.80
	4D.3 – Indirect Soil Emissions	Atm. deposition	1.72	1.33	1.12	0.97	0.88	0.88
		N-leaching and run-off	10.50	7.05	6.03	6.20	5.50	5.50
			NO	NO	NO	NO	NO	NO
	4D.4 - Other	Sewage sludges /industrial waste	0.09	0.17	0.27	0.27	0.27	0.27
		N_2O total	29.14	21.91	19.23	19.80	18.15	18.18
CO_2-eq., M tons		CH_4	4.01	3.82	3.64	3.79	3.73	3.73
		N_2O	9.03	6.79	5.96	6.14	5.63	5.63
	4. GHG – Agriculture, total		13.04	10.61	9.61	9.93	9.36	9.36

8.2 Assumptions for the projection

In this section, a short description of the assumptions is made, which is a short review of the latest base line projection made in 2008 (Poulsen et al. 2008). For dairy cows a 10 % increase is it assumed compared to Poulsen et al. (2008). This increase has been estimated because the latest development in the Danish heard of dairy cattle is slightly increasing due to the increase in the Danish milk quota. The review concerns the establishment of ammonia reducing technology in the stable, extension of biogas production, increased requirements for the utilisation of N in animal manure resulting from the VMPIII as well as the predicted assumptions for cattle and pig production. For other animal categories only minor changes are foreseen (Poulsen et al. 2008).

8.2.1 Livestock production

Slaughter pigs

More than 80 % of Danish pork is exported and the production is thus heavily dependent on conditions on the export market. The Danish pig production has increased every year until 2006, but lately the number of sows has been constant with 1.15 million sows. The number of produced pigs has increased due to an increased number of piglets per sow, but lately (from 2007) the export of piglets has increased and consequently the number of slaughtered pigs in Denmark has been reduced. The projection made by Poulsen et al. (2008) takes this development into account and is hence used in the projection.

Based on the mentioned assumptions, the production of slaughter pigs is expected to rise from the 23.1 million slaughter pigs produced in 2007 to 26.5 million in 2020 and thereafter kept constant.

Dairy cattle

Until 2007 the dairy heard has decreased with 10 000 to 15 000 dairy cows per year due to a fixed milk quota. The latest increase in the quota of 2.5 % and the expected annual increase in the milk quota of 1 % per year until 2013 combined with competitive Danish farmers will change this trend. In future it is expected that the dairy heard will decrease slightly less than previously from 545 000 in 2007 with a slight increase in 2009 to 2010 and hereafter a decrease to 457 000 in 2020. From 2020 to 2025 the number is kept constant.

8.2.2 Feed consumption and nitrogen excretion from livestock

Both the feed consumption and the nitrogen excretion affects the GHG.

For sows an increase in the feed consumption from 1470 Danish feeding units (FE) to 1600 FE in 2025 is expected. For slaughter pigs an unaltered feed consumption in terms of energy despite a slightly increase in slaughter weight is expected. This is due to an expected increase in feeding efficacy.

The nitrogen excretion from pigs is expected to continue the decrease that has been seen for the last 20 years. From 1985 to 2007, the nitrogen excretion per produced fattening pig (30-100 kg) has been reduced from 5.09 kg N to 3.10 kg combined with an increase in the slaughter weight to

107 kg. Poulsen et al. (2008) expects that the nitrogen excretion rate will continue to decrease in future to an average of 2.70 kg N per produced pig in 2020. From 2020 to 2025 is it kept constant.

For dairy cows of large breed an increase in feed consumption from 6811 FE in 2007 to 7500 FE in 2025 is expected due to increased demands for milk production. The nitrogen excretion is expected to increase from 140.2 kg N to 150 kg N in 2025.

Cattle and pig production contributes with the largest share by far of the animal manure emission – approx. 80 %. The remaining livestock categories are therefore not of much importance in assessing the future total GHG. Only minor changes in the feed consumption and nitrogen excretion has been made here.

In total the amount of nitrogen in excreted animal manure is expected to be rather constant of 250 000 tonnes per year.

8.2.3 Requirements for nitrogen utilisation in animal manure

Under evaluation of VMPIII in 2008 and 2011, a position will be taken on whether it is possible to set stricter requirements for the utilisation of the nitrogen content in animal manure of a further 4.5 – 5 %. In order to achieve the target set by VMPIII for a 13 % reduction in nitrogen leaching, as well as research in improvements of feed efficiency, this will require stricter demands for N-utilisation in animal manure. This represents the basis for the further tightening of the requirements for the utilisation of nitrogen but is not included in the projection.

8.2.4 Use of mineral fertilisers

Consumption of artificial 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 crops, which means that the total nitrogen demand per unit of area under cultivation does not change to a marked degree.

In combination with an increased gasification of slurry (which makes the nitrogen more plant accessible) and higher utilization demands and a lesser agricultural area the consumption of mineral fertiliser is assumed to be reduced from the current 200 000 tonnes per year to 165 000 tonnes.

8.2.5 N-leaching

In VMPIII, focus is furthermore directed at improvements in feed utilisation, protection of especially vulnerable habitat areas, taking areas out of production for establishment of wetlands and forest as well as stricter requirements with regard to handling animal manures. Based on these approaches, N-leaching from the root zone is expected to fall by 13 % in 2015. This corresponds to a reduction in N-leaching from 164 200 tonnes N in 2003 to approx. 142 800 tonnes N in 2015. It is assumed that the leaching in kept constant of 140 000 tonnes N from 2015 and onwards. The ongoing revision of the VMPIII has - so far - not shown any reduction in the amount of leached N from agricultural land from 2003 to 2007 so it may be difficult to reach the above mentioned target.

8.2.6 Agricultural area

In previous years the agricultural area has decreased slightly, which can be explained by an urbanisation of agricultural land. This will also take place in the future. On the other hand, the abandon of the EU set-a-side rules does increase the area where manure and mineral fertiliser application can take place. Future changes in the agricultural area are therefore expected only to have very limited effect on the consumption and leaching of nitrogen and hence these small changes are not included in the projection. This also includes the planned increase in established wetlands of 10 000 hectares as planned according to VMPIII. The current agricultural land in Denmark is approx. 2.6 million hectares.

8.2.7 Technology

Biogas production

The use of liquid slurry in the production of biogas will contribute to a reduction in the emission of CH_4 as well as N_2O.

The latest projection from the Danish Energy Agency (DEA, 2008) expects an increase in the biogas production from 4.5 PJ in 2007 to 10.0 PJ in 2020. Currently approx. 2.5 million tonnes of slurry is treated in biogas plants. The expected increase in energy yield will increase the treated amount from approx. 6 million tonnes slurry in 2020. This amount is kept constant until 2025.

Table 8.1 Expected development in liquid slurry used in biogas production 2006 to 2025.

	Million tonnes liquid slurry used in the production of biogas	Reduced emission		
		Gg CH_4	Gg N_2O	ktonnes CO_2-equiv.
2003	1.8	1.027	0.004	23
2006	2.1	1.249	0.004	28
2010	2.8	1.517	0.006	36
2025	6.5	3.793	0.013	84

Ammonia emission

The current legislation forced the farmers to reduce the ammonia emission compared to a normative ammonia emission in 2005/2006. This applies for new stables and storages and existing stables and storages if enlarged with 25 % or more.

This legislate practice is expected to continue in the future. The average life age of Danish stables are 15-20 %. As a consequence is it expected that 92 % of all pig production units and 82 % of all cattle units are renewed under these ammonia emission reducing demands (Poulsen et al. 2008).

The overall ammonia emission is therefore expected to decrease from 71 000 tonnes NH_3-N in 2006 to 56 000 tonnes in 2025. Currently, the Danish ammonia inventory is under revision, which may lower some of the used emission factors. It is expected that the current estimates are overestimated with 5-10 000 tonnes NH_3-N.

8.3 Summary

Livestock farming is moving in the direction of larger operating units, which are expected to have higher productivity compared with today's average. This entails a general increase in yield per livestock unit produced, better utilisation of feed, improved handling and utilisation of manure; measures, which lead to a reduction in GHG emissions. The emission from both ammonia and GHGs from the agricultural sector is expected to 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 in farming and developments within environmental regulation on production, especially for larger farm units. The Danish and the EU agricultural policy also plays a deciding role and, of course, the conditions for export and import of agricultural products.

In the projection, the GHG emission is expected to fall from 9 610 ktonnes CO_2 equivalents in 2006 to 9 360 ktonnes CO_2 equivalents in 2025 – corresponding to a fall of 2.6 %. The reduction in the CH_4 emission from enteric fermentation will be outweighed by an increase in the emission from manure management as a consequence of the out phasing of stables with solid manure and deep litter bedding towards slurry based systems. Furthermore, the increased feeding demand will increase the amount of volatile substance in the manure. The reduction in N_2O emission is mainly due to a reduction in N-leaching, stemming from the effects of VMPIII and a fall in the use of mineral, resulting, in turn, from improvements in the utilisation of nitrogen in animal manure.

Establishment of certain technical measures, such as ammonia-reducing measures in the stable and expansion of biogas production, is taken into account. However, as the ammonia emission is just one of the minor sources of the N_2O emission, a reduction will have limited effect on the total GHG emissions. Evaporated ammonia is one of many sources of GHG emissions, contributing with less than 3 % of the total GHG emission from agriculture. Therefore, a marked reduction in ammonia evaporation, e.g. 10 %, assuming that the remaining sources of emissions are maintained at the same level, would give a somewhat smaller reduction in the total GHG emission of 0.3 %.

Biogas treated slurry contributes to a reduction of 28 ktonnes CO_2 equivalents in 2006. This contribution is expected to increase in 2025 to 84 ktonnes without taking into account that the produced CH_4 is substituting energy consumption in other sectors. To achieve a significant effect on the total emission in the agricultural sector, a considerable increase in the existing biogas production would be required. Apart from the biogas treatment of slurry, no other technical solutions exist in agriculture today that is specifically aimed towards limiting GHGs.

8.4 Uncertainty

The uncertainty in the projected estimates is in the short term relatively precise as the GHG emission from agriculture is based on the existing production capacity. For 2020 to 2025 the estimates becomes more uncertain. This can be allocated to a number of issues:

- Danish agriculture has a very high export and is hence very dependent on the global demand and on global food prices.
- National and EU environmental policies intend to reduce the environmental impact from agriculture. The result could be a reduced number of animals in the future.
- The Danish coupling with animal production and ownership of land for manure application in combination with high costs for agricultural land may reduce further development in the animal production.
- Due to the large investments costs in stables and machinery in already established production facilities a stabilization factor is included in the emission trend. On the other hand, the current global financial crisis may delay the necessary replacement in new production facilities

The overall uncertainty in the projection in 2020-2025 is thus high. However, in 2020 it is assumed that the total GHG emission from the agricultural sector will be approx. 9,360 ktonnes CO_2-eqv. or only 2.6 % less than in 2006.

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9 Landfill sites

Deposited waste at landfill sites gives rise to CH_4 emissions.

CH_4 emissions are calculated by means of an emissions model where activity data are 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.

This chapter has not been updated in this project. In Chapter 11 the historic emissions have been updated but the projection and the text in this chapter is unchanged.

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). ISAG was used for the first time in 1993. ISAG is based on the principle that Danish waste treatment plants should register and report a range of information on all waste, which is weighed-in or weighed-out of the plants. The information for the previous year has to be reported to the Danish Environmental Protection Agency (DEPA) each year, by 31 January at the latest. The report for waste amounts for 2006 is number fourteen. The results of this reporting are published in the form of annual waste statistics, statistics for year 2006 being the latest year (DEPA, 2008). The most recent reports before this report are DEPA (2007), DEPA (2006a), DEPA (2005a), and DEPA (2004).

The annual waste statistics include the amount of waste sent to landfill.

9.2 Emissions model

The model has been developed and used in connection with the historic emission 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 2008 NIR report (Nielsen et al., 2008). In short, the model assumes that the carbon in the deposited waste decays (and is converted to CH_4. In the model, this process is assumed to unfold in such way that 10 years after deposition half of the degradable carbon has been converted to form the basis for emissions of CH_4. The model and its results have, in connection with the annual emissions inventories under the Climate Convention, been subject to reporting review processes. This results in an incentive for the model's continued use in basically unchanged form in preparation of the emission inventories. The model is built in one file in Microsoft Excel.

9.3 Historic emissions

In connection with GHG inventories for the Climate Convention, a so-called key category analysis is carried out. The analysis aggregates CO_2, CH_4, N_2O and the F-gases in relation to their respective GHG potentials and lists these on a source level in relation to the national total figures for GHG emissions. In an analysis of this type, carried out most recently for the GHGs for the year 2006, the CH_4 emission from the landfill of waste is categorised as a key-source category. This is because this source, out of the 72 sources the analysis comprises, belongs to the 23 largest sources whose GHG emission totals comprise 95 % of the national total. The landfill of waste is calculated to rank as number 13 in size among the 23 key sources. The CH_4 emission from landfill sites comprised 1.4 % of the national total in 2006. Historic emissions as well as the amounts of waste deposited are shown together with the projected waste amounts and emissions in Table 8.2. In this table, the column 'potential emissions' expresses the total emission stemming from waste landfilled in a given year and 'actual gross emissions' expresses the actual emission estimated by means of the decay model. The emission to the atmosphere is, thereafter, 'actual gross' minus CH_4 combusted in landfill gas plant.

9.4 Projections

Waste strategies have been prepared in connection with the waste plan, 'Waste 21' ('Affald 21'), which covers the period 1998-2004. Many of the initiatives in this plan relate to increased sorting of certain waste fractions, with the intention to move away from the incineration of waste towards recycling. Furthermore, the plan aims to stabilise the total amount of waste produced.

The government's 2003 'Waste Strategy 2005-2008' ('Affaldsstrategi, 2005-2008') is based on the principle of decoupling the growth in the amount of waste produced from economic growth. The projections carried out here are based on what this report mentions concerning waste targets. The results of the work on indicators in the area of waste, also mentioned in the report, may have implications for updating projections at a later date, as the desirability of recycling and incineration in relation to landfill may lead to new initiatives, which may, in turn, lead to changes in the amount of waste sent to landfill.

The waste strategy provides targets for the amount of waste to be sent to landfill for the year 2008. The reported distribution (%) for 2006 by sector of waste deposited at landfill from the Waste Statistics (DEPA, 2008) is presented in Table 9.1, along with the Waste Strategy targets for 2008.

Table 9.1 Share (%) of total landfill.

	Distribution 2006	Target 2008
Household waste	1	0
Large items of waste	21	25
Garden waste	1	0
Waste from institutions, commerce and offices	8	5
Industry	19	15
Construction	3	8
Wastewater plants	5	5
Power stations	4	10
Total	8	9

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) developed by researchers at the Department of Policy Analysis at Risø National Laboratory for Sustainable Energy, Technical University of Denmark (DEPA, 2006b). The model is a further development of the model described in the report from DEPA (DEPA, 1998) and is based on the waste data from the ISAG system as well as data for economic development from the ADAM model. Projection of the development in the amount of waste produced is based on the Ministry of Finance's projection of the economic development April 2006, on the energy strategy (Energistrategi, 2025) prepared by the Danish Ministry of Transport and Energy, as well as on ISAG data up to and including 2004.

For the amount of waste deposited at landfill, this projection uses the waste strategy 2005-2008's target, i.e. that 9 % of the total amount of waste produced goes to landfill in 2008. Furthermore, the FRIDA model's projection of total waste amount is used. With the total amount of produced waste for 2008 calculated as described, waste amounts for 2008 are then calculated on the basis of the same distribution as registered in 2006. The amount of waste for the respective waste fractions is, thereafter, interpolated between the registered values for 2006 and the projected values for 2008. After 2008, the distribution of the various waste fractions for 2003 and 2008 is retained. For 2009-2020, it is projected that the amount of waste deposited is 9 % of the Frida model's projected total waste figure. After 2020, projected waste amounts are not found in the Risø model. In this part of the projection, the total amount of waste deposited is retained as the amount projected for 2020.

The emission projection uses the same CH_4 emission model used for calculation of the historic emissions. The resulting projections of the amounts of waste produced and CH_4 emissions can be seen in Table 9.2 and Figure 9.1. For the emission of CH_4, it is characteristic of the disintegration model that the time-series fluctuations for the amount of waste deposited are not nearly as visible in the emission.

The recovery of CH_4 at landfill sites is deducted from the CH_4 emission calculated; see Table 8.2. Official energy statistics (Energistatistikken) are used for this purpose for the historic data. With regard to the projection of the amount of landfill gas recovered, the Danish Energy Agency's general projections only contain projection of biogas production, which in this connection is not viewed to be of use. In work carried out for

DEPA (Danish Environmental Protection Agency, 2005b), the company LFG-Consult (H.C. Willumsen) has reviewed Danish landfill sites. In this connection scenarios for CH_4 recovery have been prepared for the years 2005-2009. In the projections in hand, Table 9.2, a scenario (Danish Environmental Protection Agency, 2005b) has been used without optimisation of landfill sites. For the period 2010-2030, an exponential extrapolation has been carried out; see Figure 9.2.

The overall projection is shown in Table 9.3.

Model runs, which are not included here, are believed to show that the projection of the emission of the total amount of waste is of most significance for emission projections, whereas the distribution across the various waste fractions landfilled is of less importance. Closer documentation here would demand that, with data from the projections with the Risø model, landfilled waste amounts are projected, corresponding to ISAG waste fractions.

Table 9.2 Amount of waste deposited at landfill and CH_4 emissions. Historic data: 1993-2006. Projections: 2007-2025.

Year	Quantities of waste (1 000 tonnes)									Emissions (1 000 tonnes CH4)			
	House-hold	Large Items	Garden	Commer-cial	Industry	Construc-tion	Sewage sludge	Slags	Total	Potential	Actual gross	Biogas recovery	Net
1990	199	251	85	109	822	951	222	535	3175	94,7	71,1	0,5	63,6
1991	199	259	71	120	824	804	193	562	3032	93,0	72,6	0,7	64,7
1992	198	267	56	131	826	657	165	589	2890	91,3	73,9	1,4	65,2
1993	198	276	42	141	828	510	136	616	2747	89,7	74,9	1,7	65,9
1994	198	284	27	152	830	363	107	643	2604	88,0	75,8	4,6	64,1
1995	190	286	17	128	779	321	101	135	1957	83,0	76,3	7,4	62,0
1996	132	275	6	135	822	317	117	703	2507	79,3	76,5	8,2	61,5
1997	83	248	6	170	707	264	130	475	2083	73,3	76,3	11,1	58,6
1998	98	234	20	161	746	266	124	210	1859	73,6	76,1	13,2	56,6
1999	117	239	3	164	582	224	126	12	1467	70,6	75,7	11,5	57,8
2000	85	264	7	152	611	269	94	0	1482	69,5	75,3	11,0	57,9
2001	50	180	3	150	583	260	64	10	1300	55,4	74,0	10,0	57,6
2002	37	161	4	137	520	229	48	38	1174	48,8	72,3	11,2	55,0
2003	24	143	4	131	379	170	55	60	966	41,8	70,2	7,9	56,1
2004	11	132	5	140	452	172	42	46	1000	41,7	68,3	11,0	51,6
2005	12	165	5	152	352	208	35	28	957	43,8	66,7	11,5	49,7
2006	13	156	6	152	375	204	39	31	976	43,7	65,2	10,8	49,0
2007	15	180	7	176	433	236	45	36	1127	50,5	64,2	6,5	51,9
2008	17	204	8	199	491	267	51	41	1278	57,2	63,7	6,0	51,9
2009	17	206	8	201	495	269	51	41	1288	57,6	63,3	5,7	51,9
2010	17	205	8	199	492	267	51	41	1280	57,3	62,9	5,3	51,8
2011	17	208	8	202	499	271	52	41	1299	58,1	62,6	5,0	51,8
2012	17	209	8	204	503	273	52	42	1308	58,6	62,3	4,7	51,8
2013	18	212	8	206	509	277	53	42	1325	59,3	62,1	4,5	51,9
2014	18	213	8	207	511	278	53	42	1330	59,5	61,9	4,3	51,9
2015	18	215	8	210	517	281	54	43	1346	60,3	61,8	4,1	52,0
2016	18	215	8	210	518	282	54	43	1348	60,3	61,7	3,9	52,0
2017	18	216	8	211	520	283	54	43	1354	60,6	61,6	3,8	52,1
2018	18	218	8	212	523	285	54	43	1362	61,0	61,6	3,6	52,2
2019	18	218	8	213	524	285	55	43	1365	61,1	61,6	3,5	52,2
2020	18	220	8	215	529	288	55	44	1377	61,7	61,6	3,4	52,4
2021	18	220	8	215	529	288	55	44	1377	61,7	61,6	3,3	52,4
2022	18	220	8	215	529	288	55	44	1377	61,7	61,6	3,2	52,5
2023	18	220	8	215	529	288	55	44	1377	61,7	61,6	3,1	52,6
2024	18	220	8	215	529	288	55	44	1377	61,7	61,6	3,1	52,7
2025	18	220	8	215	529	288	55	44	1377	61,7	61,6	3,0	52,7

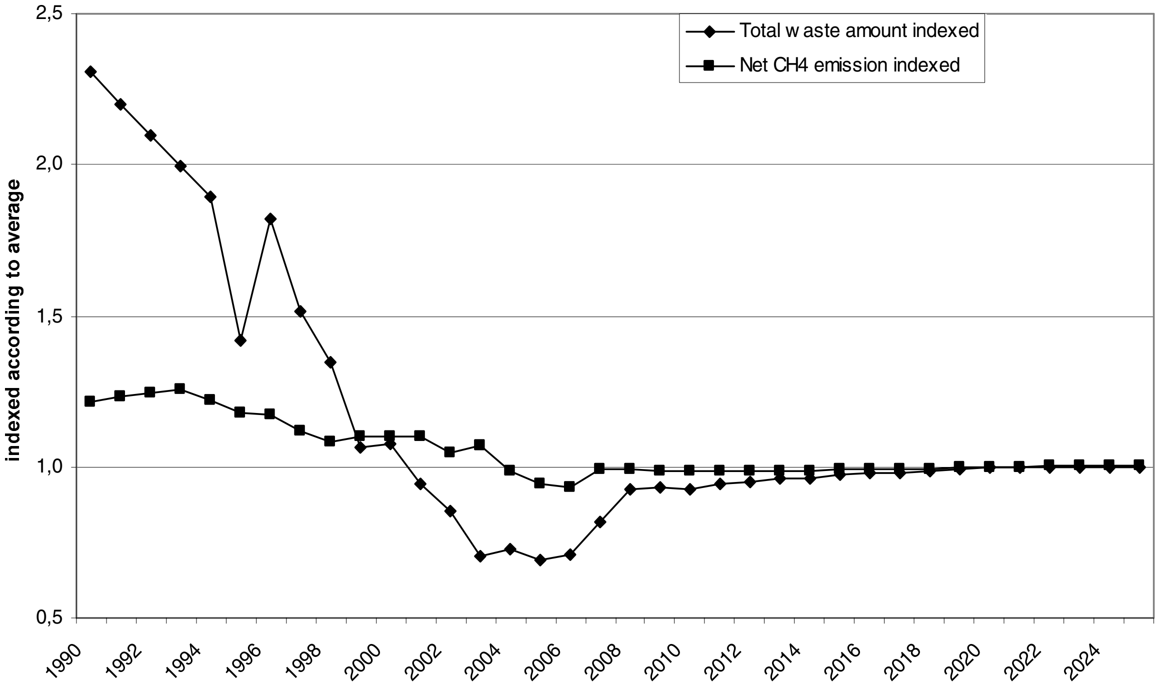

Figure 9.1 Development of waste deposited at landfill and CH_4 emissions. Historic data: 1993-2006. Projections: 2007-2025. Indexation is in relation to the time-series average for the relevant parameter.

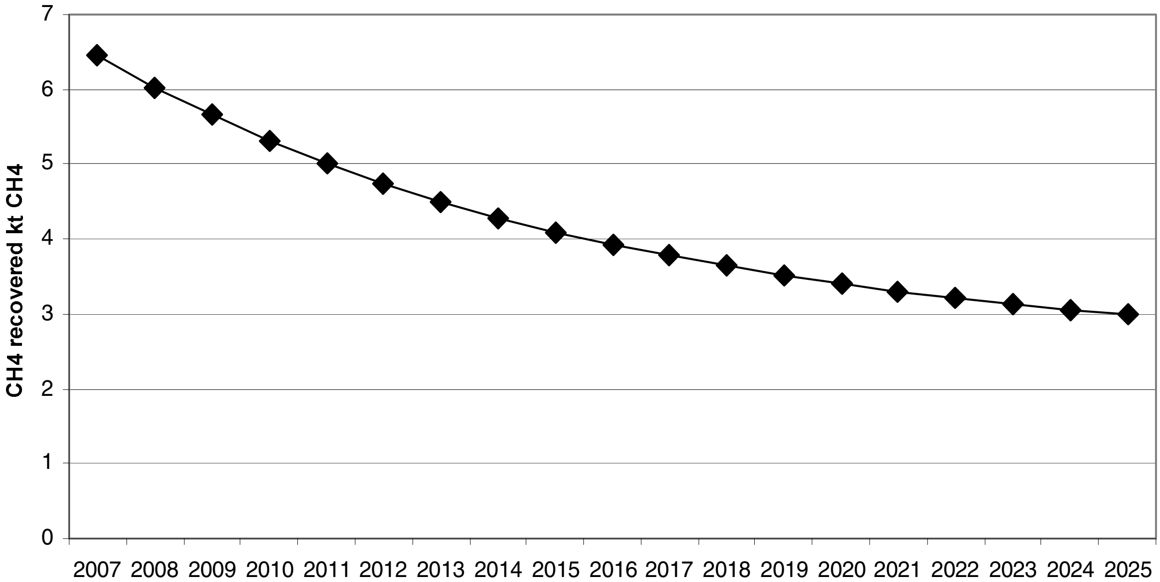

Figure 9.2 Projection of CH_4 recovery at landfill sites. For 2007-2009 data according to Danish Environmental Protection Agency (DEPA 2005b). For 2009-2025: exponential extrapolation.

Table 9.3 Emission of CH_4 from landfill of waste in CO_2-eqv. (1 000 tonnes =Gg). Historic data: 1993-2006. Projections: 2007-2025.

CRF-sector	Year Note	1990	1995	2000	2005	2007	2010 1)	2015 2)	2020	2025
6. Solid waste disposal on Land										
1. Managed Waste Disposal on Land		1335.2	1301.2	1215.4	1042.8	1090.8	1088.7	1091.1	1099.4	1107.6

Note:

1) 5-year average 2008-2012.

2) 5-year average 2013-2017.

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10 Wastewater treatment

Below, a short overview of the emission inventories of CH_4 and N_2O from wastewater treatment from 1990 to 2008 is provided and based on the latest National Inventory Report (Nielsen et al., 2010a). Furthermore, an overview of methodology and projected data for 2009 to 2030 are presented.

The calculations of CH_4 emissions are based on the theoretical maximum emission; here termed 'gross methane emission'. This gross methane emission corresponds to the maximum CH_4 producing capacity in the fraction of the biodegradable organic material in the influent wastewater at the wastewater treatment plants (WWTPs) that are treated at anaerobic conditions. The amount of recovered CH_4 gas, i.e. biogas, produced in closed systems and used for energy production is then subtracted from the gross methane emission. The resulting net CH_4 emission is an estimate of the real CH_4 emission from treatment processes at WWTPs.

Central input parameters are the industrial contribution to the wastewater entering wastewater treatment plants as well as the fraction of sewage sludge, which is treated by anaerobic stabilisation. The methodology used in the latest National Inventory Report includes a recalculation of the entire time-series 1990-2007 resulting in significant changes in the net CH_4 emission. For details regarding the calculation methodologies, please refer to the National Inventory Report (Nielsen et al., 2010a and Nielsen et al., 2010b).

Emission calculations for N_2O are divided into the contribution from the treatment processes at the WWTPs, termed the direct emission, and a contribution from the discharges from the wastewater treatment plants, termed the indirect N_2O emission. A new methodology has been adopted for estimating the direct N_2O emission, which relies on the influent N load as activity data and a national derived emission factor of 4.99 g N_2O per kg N load in the influent wastewater. For details regarding the adopted methodology and derivation of national N_2O emissions factors please refer to Nielsen et al., 2010a and Nielsen et al., 2010b).

Due to incompleteness in reported sludge amounts per year, it is not feasible at this stage to derive time trends for the national emission factor for the direct N_2O emissions, even though the technological development at the Danish WWTPs may suggest the N_2O emission factor to have changed over time. To develop a time trend for emission factor a mass balance of the total nitrogen in the influent, effluent wastewater and the final sludge is required (Nielsen et al., 2010b). Furthermore, a methodology for the estimation of the percent composition of N_2, NO_x, NH_3 and N_2O gas emissions will have to be developed and a project for the improvement of sludge statistics as well as emission inventory preparation for the components to be reported to UNECE has been proposed to the Danish EPA.

Table 10.1 Estimates of N_2O, i.e. direct, indirect and total, and of CH_4, i.e. gross, not emitted and net, emission profiles from 1990 to 2030, [Gg]. Inventories: 1990-2008. Projections: 2009-2030.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
$E(N_2O_{WWTP,direct})$	0.077	0.081	0.076	0.079	0.118	0.118	0.119	0.122	0.133
$E(N_2O_{, effluents})$	0.265	0.252	0.219	0.273	0.268	0.238	0.180	0.158	0.154
$E(N_2O_{, total})$	0.343	0.333	0.296	0.352	0.386	0.356	0.298	0.281	0.287
$E(CH_{4, gross})$	14.493	14.459	14.507	14.912	16.196	17.489	18.791	20.103	21.420
$E(CH_{4, not emitted})$	13.044	13.013	13.056	13.421	14.576	15.740	16.912	18.093	19.278
$E(CH_{4,net})$	1.449	1.446	1.451	1.491	1.620	1.749	1.879	2.010	2.142

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007
$E(N_2O_{WWTP,direct})$	0.130	0.142	0.145	0.185	0.148	0.132	0.170	0.134	0.163
$E(N_2O_{, effluents})$	0.147	0.157	0.134	0.137	0.109	0.119	0.111	0.109	0.100
$E(N_2O_{, total})$	0.277	0.299	0.279	0.323	0.256	0.251	0.280	0.242	0.263
$E(CH_{4, gross})$	21.038	21.223	21.654	23.427	24.032	22.959	22.474	21.989	22.505
$E(CH_{4, not emitted})$	18.934	19.101	19.489	21.084	21.629	20.663	20.227	19.790	20.255
$E(CH_{4,net})$	2.104	2.122	2.165	2.343	2.403	2.296	2.247	2.199	2.251

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
$E(N_2O_{WWTP,direct})$	0.225	0.227	0.232	0.236	0.240	0.244	0.247	0.251	0.254
$E(N_2O_{, effluents})$	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112
$E(N_2O_{, total})$	0.337	0.339	0.343	0.348	0.352	0.355	0.359	0.362	0.366
$E(CH_{4, gross})$	22.537	22.568	22.600	22.631	22.663	22.694	22.726	22.757	22.788
$E(CH_{4, not emitted})$	20.283	20.311	20.340	20.368	20.396	20.425	20.453	20.481	20.510
$E(CH_{4,net})$	2.254	2.257	2.260	2.263	2.266	2.269	2.273	2.276	2.279

Year	2017	2018	2019	2020	2021	2022	2023	2024	2025
$E(N_2O_{WWTP,direct})$	0.257	0.261	0.264	0.267	0.271	0.274	0.278	0.281	0.284
$E(N_2O_{, effluents})$	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112
$E(N_2O_{, total})$	0.369	0.372	0.376	0.379	0.383	0.386	0.390	0.393	0.396
$E(CH_{4, gross})$	22.820	22.851	22.883	22.914	22.946	22.977	23.009	23.040	23.071
$E(CH_{4, not emitted})$	20.538	20.566	20.594	20.623	20.651	20.679	20.708	20.736	20.764
$E(CH_{4,net})$	2.282	2.285	2.288	2.291	2.295	2.298	2.301	2.304	2.307

Year	2026	2027	2028	2029	2030
$E(N_2O_{WWTP,direct})$	0.288	0.290	0.293	0.296	0.298
$E(N_2O_{, effluents})$	0.112	0.112	0.112	0.112	0.112
$E(N_2O_{, total})$	0.399	0.402	0.405	0.407	0.410
$E(CH_{4, gross})$	23.103	23.134	23.166	23.197	23.229
$E(CH_{4, not emitted})$	20.793	20.821	20.849	20.878	20.906
$E(CH_{4,net})$	2.310	2.313	2.317	2.320	2.323

The CH_4 emission are derived, assuming that the CH_4 gas produced during anaerobic stabilisation are used for energy production on-site and that biogas for energy production external the WWTP, occurs in closed systems. Adopting a value of 10 % covering fugitive emission (IPPC, 2006) from anaerobic stabilisation, including reactors, digestion and storage tanks (Nielsen et al., 2010b) may seem high. The high end value are chosen with the purpose of explicitly accounting for unintentional produced CH_4 released as fugitive emissions from the sewerage system and aerobic treatment systems, e.g. lagoons, septic tanks and latrines. The adjusted methodology makes the CH_4 emission a function of the influent organic degradable waste at the WWTPs only. The net emissions are calculated according to the equation below.

$$CH_{4,net} = 0.1 \cdot CH_{4,gross}$$

where the gross emission is calculated from the total organic degradable waste (TOW) in the influent wastewater and an emissions actor accounting for the amount of sludge treated anaerobically (cf. Thomsen & Lyck, 2005). For background information on the validation of activity data and adopted approach for the submission 2010 and projection in this report please refer to Nielsen et al., 2010b.

The trend from 1990 to 2008, as well as the projection to 2030, is shown in Table 10.2 and Figures 10.1 and 10.2.

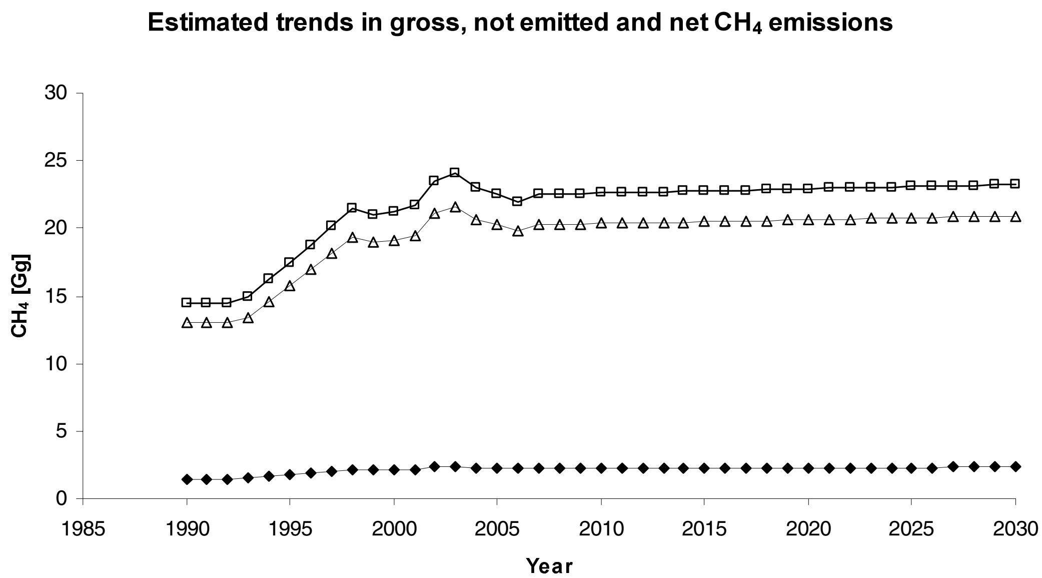

Figure 10.1 Estimated trends in gross CH_4 potential (open squares), not emitted CH_4 potential (black open triangles), i.e. consisting mainly of recovered biogas from anaerobic treatment for energy production, and the resulting net CH_4 emission, and emitted CH_4 (black squares).

The projection of the gross emission is based on the methodology also used for estimating TOW. An official projection is not yet available from the Agency for Spatial and Environmental Planning (ASEP); i.e. an average of i) the average of the last three years reported TOW by the ASEP following the hypothesis of the TOW level having reached a constant level (ASEP, 2009; Nielsen et al., 2010b) and ii) the default methodology as derived in Thomsen & Lyck, 2005 assuming a linear increased in TOW according to the population number.

The emission of N_2O from wastewater treatment plants is divided into a direct emission from biological treatment processes at the plants and an indirect emission from the nitrogen, which exits the plants with the discharge of effluent wastewater. The total emission of N_2O is the sum of these two contributions.

Calculation of the projected direct emission are based on an assumption of the direct emissions to be linearly related to the population size assuming that the contribution from the industry has reached a constant level from 1997 and onwards. The slope of the regression line quantifying the direct emission as function of population size from 1997 to 2008 was used for the projection to year 2030. The indirect N_2O emissions were kept constant. The estimated trend in indirect and direct N_2O emission from 1990 to 2030 is given in Table 10.1 and illustrated graphically in Figure 10.x.

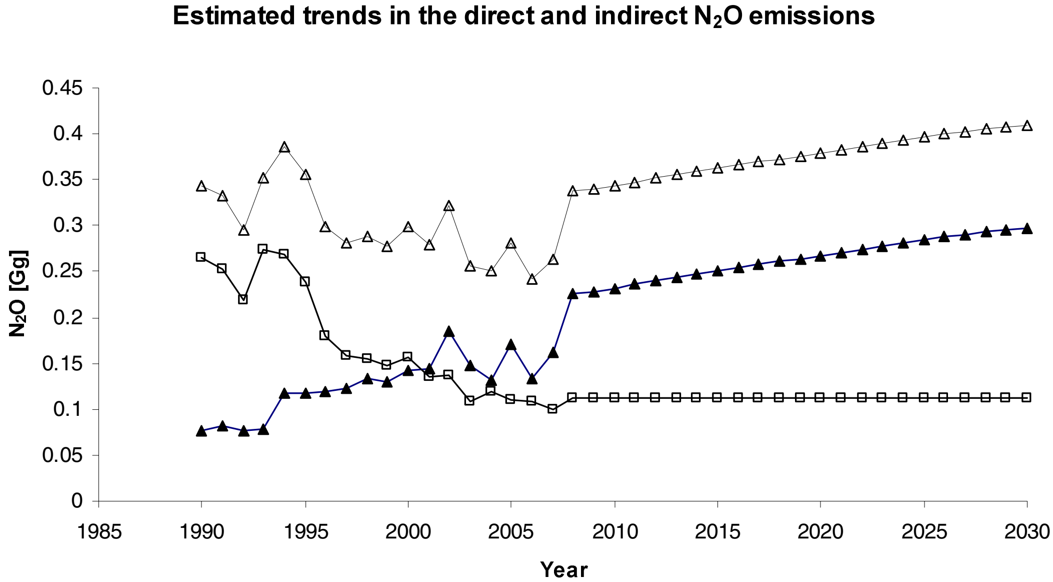

Figure 10.2 Patterns and trends for direct (closed triangles), indirect (open squares) and total (open triangles) N_2O emissions from wastewater treatment processes at sewage treatment plants. Fluctuations from 1990-2008 expresses the relatively large uncertainty in the average national data for the content of nitrogen and resulting N_2O emissions from wastewater treatment processes in Denmark.

Total N_2O and net CH_4 emission figures converted to CO_2 equivalents are given in Table 10.2 and the sum up result for emissions from wastewater in total is given in Table 10.3.

Table 10.2 N_2O and CH_4 emissions in Gg CO_2 equivalents.
Inventories: 1990-2008. Projections: 2009-2030.

Emissions in CO_2-equiv. (Gg)		
Year	N_20	CH_4
1990	106.20	30.44
1991	103.23	30.36
1992	91.62	30.46
1993	109.27	31.32
1994	119.66	34.01
1995	110.46	36.73
1996	92.53	39.46
1997	86.98	42.22
1998	89.06	44.98
1999	85.98	44.18
2000	92.72	44.57
2001	86.54	45.47
2002	100.00	49.20
2003	79.50	50.47
2004	77.75	48.21
2005	86.95	47.20
2006	75.09	46.18
2007	81.45	47.26
2008	104.51	47.33
2009	105.04	47.39
2010	106.45	47.46
2011	107.76	47.53
2012	108.99	47.59
2013	110.15	47.66
2014	111.26	47.72
2015	112.33	47.79
2016	113.37	47.86
2017	114.41	47.92
2018	115.46	47.99
2019	116.51	48.05
2020	117.57	48.12
2021	118.64	48.19
2022	119.71	48.25
2023	120.78	48.32
2024	121.83	48.38
2025	122.84	48.45
2026	123.80	48.52
2027	124.70	48.58
2028	125.54	48.65
2029	126.29	48.71
2030	126.95	48.78

Table 10.3 Sum of the emission of CH_4 and N_2O from wastewater treatment in Gg CO_2 equivalents.

CRF-sektor	År	1990	1995	2000	2005	2008	2010	2015	2020	2025	2030
	Note						1)	2)			
6. B Waste Water Handling		136.6	147.2	137.3	134.1	151.8	154.0	160.1	165.7	171.3	175.7

Note: 1) 5-year average 2008-2012.
2) 5-year average 2013-2017.

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11 Conclusions

The historic and projected greenhouse gas (GHG) emissions are shown in Tables 11.1 – 11.9 and illustrated in Figure 11.1. Projected GHG emissions include the estimated effects of policies and measures implemented until April 2010 and the projection of total GHG emissions is therefore a so-called 'with measures' projection.

The main sectors in the years 2008-2012 ('2010') are expected to be Energy Industries (36 %), Transport (22 %), Agriculture (17 %) and Other Sectors (11 %). For the latter sector the most important sources are fuel use in the residential sector and the agricultural sector. GHG emissions show a decreasing trend in the projection period from 2009 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 59 843 ktonnes CO_2 equivalents and 53 978 ktonnes in 2030, corresponding to a decrease of about 10 %. From 1990 to '2010' the emissions are estimated to decrease by about 13 %. 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.

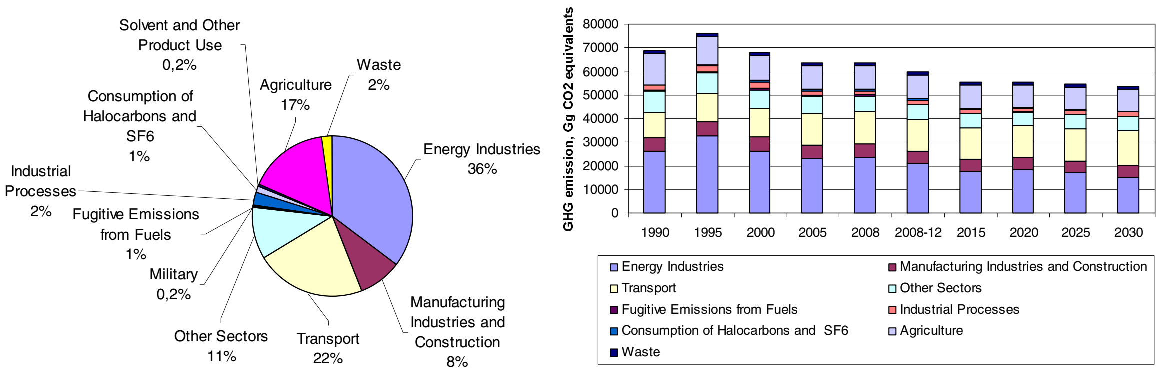

Figure 11.1 Total GHG emissions in CO_2 equivalents. Distribution according to main sectors ('2010') and time-series for 1990 to 2025.

11.1 Stationary combustion

The GHG emissions in '2010' from the main source, which is public power (60 %), are estimated to decrease significantly in the period from 2008 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 60 % 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 20 % from '2010' to 2030.

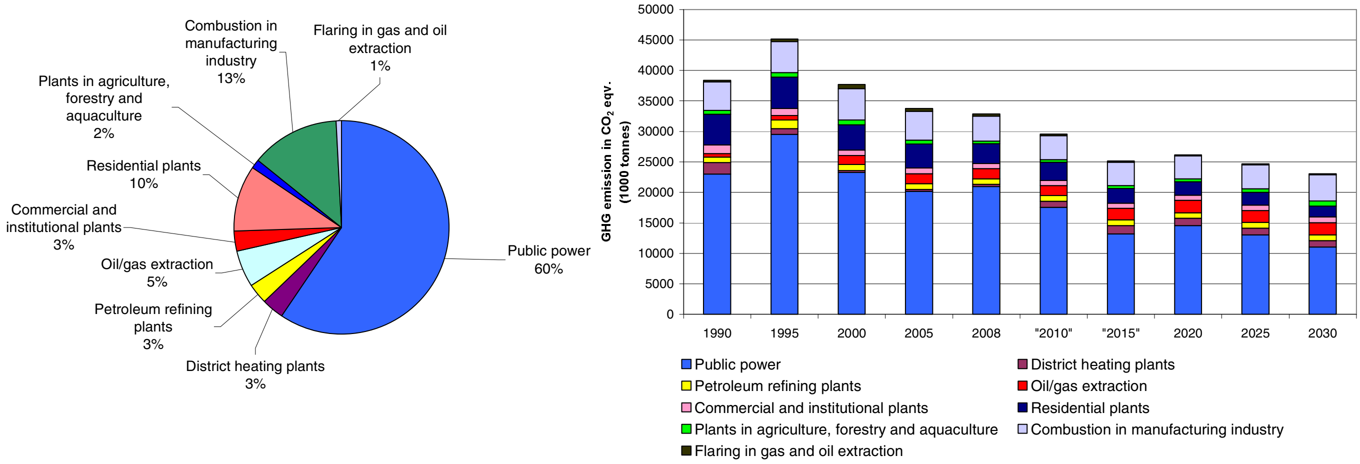

Figure 11.2 GHG emissions in CO_2 equivalents for stationary combustion. Distribution according to sources ('2010') and time-series for 1990 to 2030 for main sources.

11.2 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 and stabilisation at a level about 1 500 ktonnes CO_2 equivalents. The most significant source is cement production, which contributes with 87 % of the process-related GHG emission. Most of the processes are assumed to be constant at the same level as in 2008. 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.

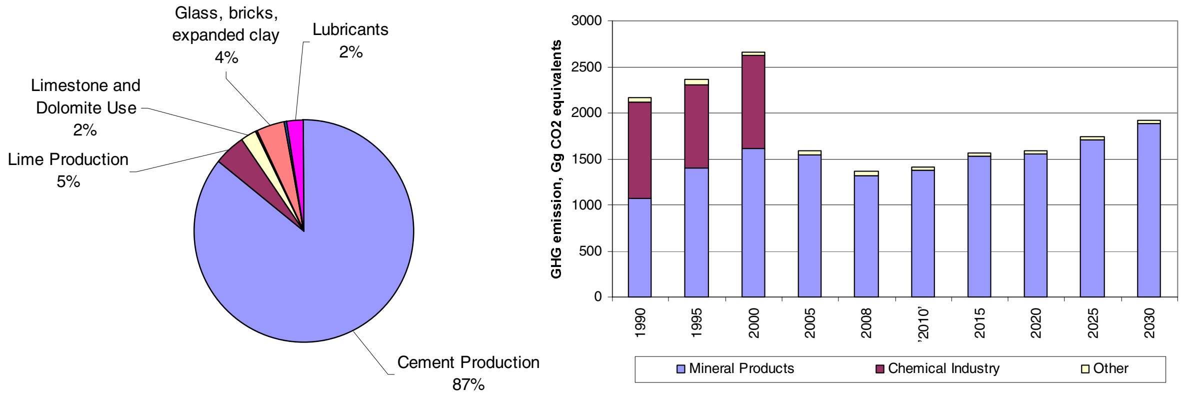

Figure 11.3 Total GHG emissions in CO_2 equivalents for industrial processes. Distribution according to main sectors ('2010') and time-series for 1990 to 2025.

11.3 Solvents

The projection for solvents has not been updated since 2008. The projected emissions are therefore not totally consistent with the latest historical data.

In 2006 solvent and other product use account for 0.3 % of the total CO_2 emissions. Emission projections from 2006 to 2010 are based on linear projections of 1995 – 2006 historical data and projections of four industrial sectors, namely "Auto paint and repair", "Plastic industry", "Graphic industry" and "Lacquer and paint industry", comprising approximately 27 % of the total GHG emission from solvent and other product use in '2010'. Constant emissions are assumed from 2010 to 2030. Households, construction, plastic industry, industrial mass produced products and auto paint and repair are the largest sources to the Danish VOC emissions from solvent use.

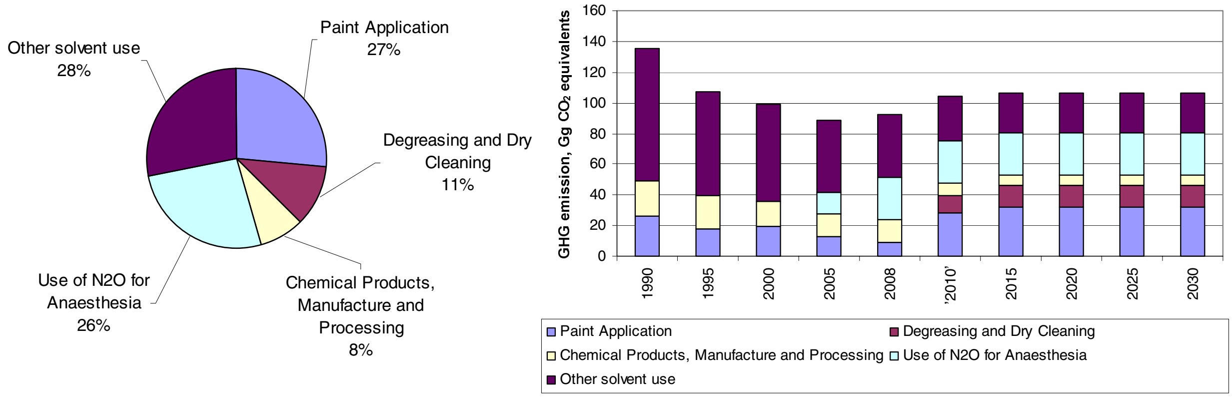

Figure 11.4 Total GHG emissions in CO_2 equivalents for solvent use. Distribution according to main sectors ('2010') and time-series for 1990 to 2030.

11.4 Transport

Road transport is the main source of GHG emissions in '2010' and emissions from this sector are expected to increase by 43 % 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 31 % to 25 %. For agriculture/forestry/fisheries, the emissions increase by 13 % from 1990 to 2030. For this sector, the emissions reduce from 1990 to 2005 due to smaller numbers of agricultural tractors and harvesters though with larger engines. For industry (1A2f), the emissions increase by 35 % from 1990-2030. For this sector there is a significant emission growth from 1990-2008 (due to increased activity), followed by an almost constant level of GHG emissions from 2008 onwards, due to gradually more fuel efficient machinery, which outbalances a small increase in activity in terms of emission impact.

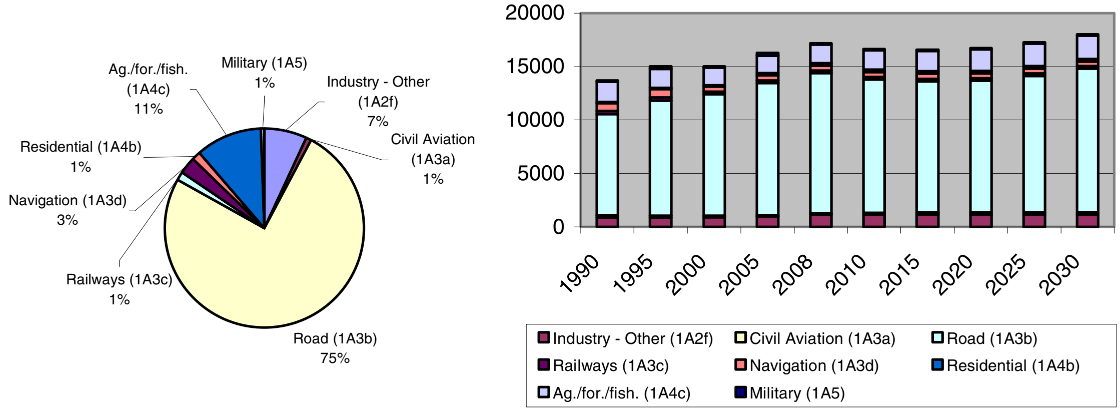

Figure 11.5 GHG emissions in CO_2 equivalents for mobile sources. Distribution according to sources ('2010') and time-series for 1990 to 2030 for main sources.

11.5 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 92 % of the F-gas emission, Figure 11.6.

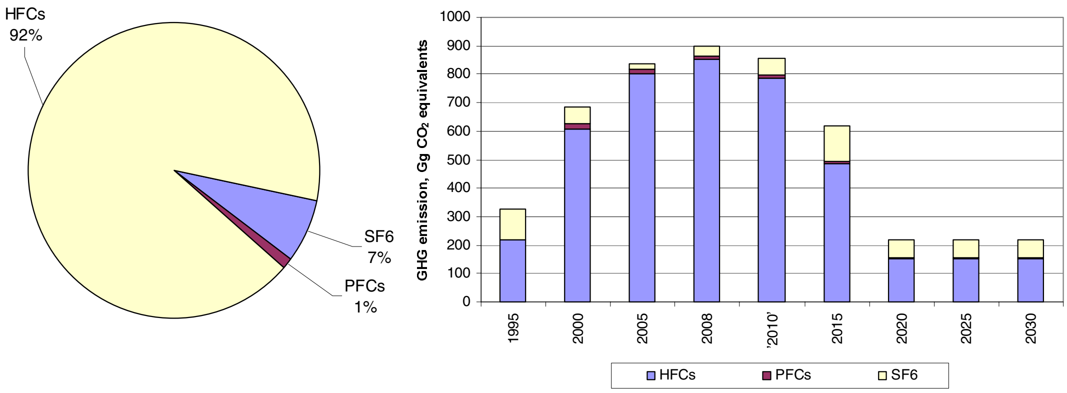

Figure 11.6 GHG emissions in CO_2 equivalents for F-gases. Distribution according to F-gas type ('2010') and time-series for 1990 to 2030 for F-gas type.

11.6 Agriculture

The projection of emissions from agriculture has not been updated in connection with this project.

From 1990 to 2008, the emission of GHGs in the agricultural sector has declined from 13 109 ktonnes CO_2 equivalents to 10 025 ktonnes CO_2 equivalents, which corresponds to a 24 % reduction. This development continues and the emission to 2030 is expected to fall further to 9 363 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 fall 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 but do not contribute to significant changes in the total GHG emission.

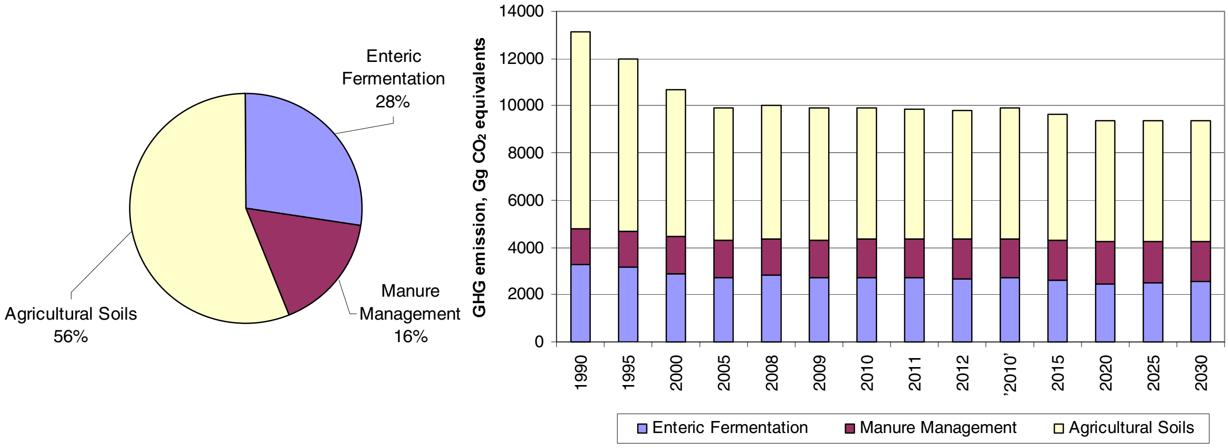

Figure 11.7 GHG emissions in CO_2 equivalents for agriculture sources. Distribution according to sources ('2010') and time-series for 1990 to 2030 of main sources.

11.7 Waste

The target in the government's 2003 'Waste Strategy 2005-2008' ('Affaldsstrategi 2005-2008') of 9 % of waste produced to be deposited at landfill sites in 2008 has been used in combination with the Risø FRIDA model for amounts of waste coupled with economic growth. The waste strategy target has already been reached (8 % in 2004). A slight increase in the amount of waste deposited is now foreseen due to an increase in the amount of waste produced predicted by FRIDA. In the historical data, the amount of waste deposited at landfill decreased; so, after some years with decreasing CH_4 emissions, a slight increase or an almost constant emission level is now foreseen. However, there exists a time-lag between reductions in the amount of waste deposited at landfill and the associated CH_4 emission due to the duration of the biochemical processes involved, which is predicted by the decay model used for the emission estimates. The prediction of the contribution of CH_4 from landfill to the sector total in '2010' is 85 %, Figure 11.8.

The predicted GHG emission from wastewater is 12 %. 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.

Calculation of the projected direct emission are based on an assumption of the direct emissions to be linearly related to the population size assuming that the contribution from the industry has reached a constant level from 1997 and forward. The slope of the regression line quantifying the direct emission as function of population size from 1997 to 2008 was used for projection until 2030. The indirect N_2O emissions were kept constant.

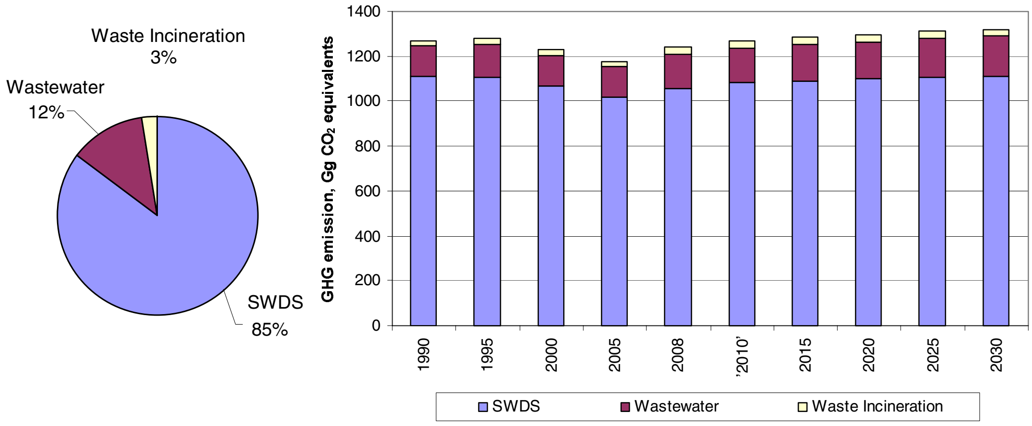

Figure 11.8 GHG emissions in CO_2 equivalents for Waste. Distribution according to main sources ('2010') and the time-series for 1990 to 2030.

Table 11.1 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**	**68878**	**76340**	**68295**	**63827**	**63845**	**62631**	**58162**	**56686**	**57908**	**59843**	**55579**	**55518**	**54704**	**53978**
1. Energy		**52121**	**52168**	**60253**	**52877**	**50216**	**50231**	**49108**	**44589**	**43152**	**44379**	**46292**	**42352**	**42945**	**41962**	**41048**
A. Fuel Combustion (Sectoral Approach)		**51817**	**51824**	**59770**	**52130**	**49609**	**49725**	**48849**	**44337**	**42887**	**44112**	**45982**	**42126**	**42732**	**41751**	**40846**
1. Energy Industries		**26315**	**26357**	**32603**	**26039**	**23063**	**23868**	**24165**	**19615**	**18387**	**19648**	**21137**	**17839**	**18706**	**16997**	**14979**
a Public Electricity and Heat Production		24861	24903	30472	23573	20501	21317	21588	17062	15822	17048	18567	15142	15747	14128	12109
b Petroleum Refining		908	908	1387	999	938	923	982	982	982	982	970	982	982	982	982
c Manufacture of Solid Fuels and Other Energy Industries		546	546	744	1467	1623	1628	1596	1572	1583	1619	1600	1716	1978	1888	1888
2. Manufacturing Industries and Construction		**5493**	**5493**	**5966**	**6105**	**5688**	**5278**	**4993**	**5018**	**5033**	**5081**	**5081**	**5037**	**4912**	**5084**	**5433**
3. Transport		**10529**	**10700**	**12052**	**12252**	**13223**	**13963**	**13208**	**13271**	**13176**	**13148**	**13353**	**13184**	**13226**	**13678**	**14340**
a Civil Aviation		246	246	202	157	137	167	167	169	172	175	170	184	207	217	213
b Road Transport		9418	9427	10764	11380	12371	13096	12341	12403	12305	12275	12484	12303	12322	12764	13444
c Railways		300	300	306	230	234	239	239	239	239	239	239	239	239	239	239
d Navigation		566	728	781	485	480	462	461	461	460	459	461	458	458	458	444
4. Other Sectors		**9359**	**9153**	**8894**	**7623**	**7361**	**6507**	**6373**	**6324**	**6184**	**6128**	**6303**	**5959**	**5782**	**5885**	**5988**
a Commercial and Institutional		1419	1422	1156	920	965	843	871	881	872	869	867	868	865	893	927
b Residential		5208	5183	5253	4282	4143	3504	3284	3203	3050	2967	3202	2722	2411	2328	2057
c Agriculture/Forestry/Fisheries		2732	2549	2485	2421	2254	2160	2218	2239	2261	2292	2234	2369	2506	2663	3004
5. Other	(1)	**120**	**120**	**255**	**112**	**274**	**109**	**109**	**109**	**107**	**106**	**108**	**106**	**106**	**106**	**106**
B. Fugitive Emissions from Fuels		**304**	**344**	**483**	**747**	**607**	**505**	**259**	**252**	**266**	**267**	**310**	**226**	**213**	**211**	**203**
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**	**483**	**747**	**607**	**505**	**259**	**252**	**266**	**267**	**310**	**226**	**213**	**211**	**203**
a Oil		32	33	48	72	97	121	62	29	32	33	56	37	38	36	29
b Natural Gas		6	9	18	10	9	6	5	5	5	5	5	5	4	3	3
c Flaring		267	302	417	665	501	378	192	218	229	229	249	185	171	171	171
2. Industrial Processes		**2470**	**2195**	**2727**	**3389**	**2442**	**2257**	**2237**	**2256**	**2273**	**2323**	**2268**	**2187**	**1804**	**1960**	**2139**
A. Mineral Products		**1072**	**1069**	**1405**	**1616**	**1544**	**1320**	**1321**	**1366**	**1399**	**1468**	**1375**	**1529**	**1548**	**1704**	**1883**
1 Cement Production		882	882	1204	1385	1363	1155									
2 Lime Production		152	116	88	77	63	66									
3 Limestone and Dolomite Use		18	14	54	90	56	39									

4 Soda Ash Production and Use	NO	0	0	0	0	0	0									
5 Asphalt Roofing	(<0,5)	0	0	0	0	0	0									
6 Road Paving with Asphalt		2	2	2	2	2	2									
7 Other	(2)	17	55	58	63	59	60									
B. Chemical Industry		**1044**	**1044**	**905**	**1004**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
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	2	2
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**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
E. Production of Halocarbons and SF_6	NO															
F. Consumption of Halocarbons and SF_6		**290**	**0**	**290**	**663**	**838**	**897**	**877**	**851**	**835**	**816**	**854**	**619**	**217**	**217**	**217**
1. Refrigeration and Air Conditioning Equipment		36	0	36	436	676	739	8	7	6	6	7	4	2	2	2
2 Foam Blowing		183	0	183	168	119	103	0	0	0	0	0	0	0	0	0
3 Fire Extinguishers		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 Aerosol/Metered Dose Inhalers		0	0	0	19	21	19	0	0	0	0	0	0	0	0	0
8 Electrical Equipment		4	0	4	11	13	16	17	17	17	17	17	18	20	20	20
9 Other		**68**	**0**	**68**	**29**	**9**	**21**	**23**	**23**	**56**	**101**	**44**	**108**	**43**	**43**	**43**
C_3F_8	(4)	0	0	0	2	0	4	0	0	0	0	0	0	0	0	0
SF_6	(5)	68	0	68	27	9	15	23	23	56	101	44	108	43	43	43
G. Other		**NO**	**50**	**49**	**40**	**38**	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**34**
3. Solvent and Other Product Use		**137**	**135**	**107**	**99**	**88**	**92**	**110**	**107**	**107**	**107**	**105**	**107**	**107**	**107**	**107**
A Paint Application		24	26	18	19	12	9	34	32	32	32	28	32	32	32	32
B Degreasing and Dry Cleaning		46	0	0	0	0	0	14	14	14	14	11	14	14	14	14
C Chemical Products, Manufacture and Processing		3	23	21	16	15	15	7	7	7	7	8	7	7	7	7
D Other		**64**	**86**	**68**	**63**	**61**	**68**	**55**	**54**	**54**	**54**	**57**	**54**	**54**	**54**	**54**
1 Use of N_2O for Anaesthesia		NE	NE	NE	NE	14	27	27	27	27	27	27	27	27	27	27
5 Other	(6)	64	86	68	63	47	41	28	26	26	26	30	26	26	26	26
4. Agriculture		**13048**	**13109**	**11975**	**10698**	**9901**	**10025**	**9903**	**9936**	**9879**	**9822**	**9910**	**9650**	**9365**	**9364**	**9363**
A Enteric Fermentation		**3259**	**3261**	**3135**	**2876**	**2724**	**2819**	**2702**	**2738**	**2710**	**2683**	**2730**	**2600**	**2462**	**2498**	**2535**
1 Cattle		**2950**	**2950**	**2787**	**2486**	**2298**	**2382**									
Dairy Cattle		1844	1844	1762	1564	1518	1528									
Non-Dairy Cattle		1106	1106	1025	921	780	854									
2 Buffalo		NO														

3 Sheep		33	33	29	40	46	42									
4 Goats		2	2	2	2	3	4									
5 Camels and Llamas	NO															
6 Horses		60	60	64	67	78	87									
7 Mules and Asses	NO															
8 Swine		213	213	250	278	297	302									
9 Poultry	NE															
10 Other		**0**	**2**	**2**	**2**	**2**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fur farming & Deer	NE	0	2	2	2	2	2	0	0	0	0	0	0	0	0	0
B. Manure Management		**1437**	**1536**	**1556**	**1567**	**1587**	**1555**	**1626**	**1639**	**1654**	**1669**	**1629**	**1712**	**1785**	**1740**	**1695**
1 Cattle		**282**	**497**	**466**	**447**	**434**	**429**									
Dairy Cattle		213	346	335	332	346	338									
Non-Dairy Cattle		69	151	131	115	88	91									
2 Buffalo	NO															
3 Sheep		1	1	1	1	1	1									
4 Goats		0	0	0	0	0	0									
5 Camels and Llamas	NO															
6 Horses		4	9	9	10	12	12									
7 Mules and Asses	NO															
8 Swine		448	323	421	485	521	541									
9 Poultry		6	10	11	11	10	13									
10 Other livestock		**9**	**28**	**24**	**32**	**42**	**54**									
Fur farming		9	28	24	32	42	54									
11 Anaerobic Lagoons	NO															
12 Liquid Systems		96	89	78	75	74	75									
13 Solid Storage and Dry Lot		589	577	544	507	492	431									
14 Other AWMS	NO															
C. Rice Cultivation	NO															
D. Agricultural Soils		**8352**	**8309**	**7282**	**6250**	**5585**	**5647**	**5571**	**5555**	**5511**	**5467**	**5550**	**5335**	**5115**	**5122**	**5130**
1 Direct Soil Emissions		4225	4220	3638	3252	3071	3154									
2 Pasture, Range and Paddock Manure		312	314	325	314	239	214									
3 Indirect Emissions		3787	3775	3318	2684	2276	2279									
4 Other		**28**	**IE**	**IE**	**IE**	**IE**	**IE**									
Industrial waste used as fertilizer		9	IE	IE	IE	IE	IE									
Use of sewage sludge as fertilizers		19	IE	IE	IE	IE	IE									
E. Prescribed Burning of Savannas	NO															

F. Field Burning of Agricultural Residues		**NO**	3	3	4	4	3	3	3	3	3	3	3	3	3	3
G. Other	NO															
6. Waste		**1547**	**1271**	**1279**	**1233**	**1179**	**1241**	**1274**	**1274**	**1275**	**1277**	**1268**	**1283**	**1297**	**1311**	**1321**
A. Solid Waste Disposal on Land		**1334**	**1111**	**1104**	**1069**	**1019**	**1057**	**1089**	**1088**	**1088**	**1088**	**1082**	**1091**	**1099**	**1108**	**1113**
B. Waste-water Handling		**213**	**137**	**147**	**137**	**134**	**152**	**152**	**154**	**155**	**157**	**154**	**160**	**166**	**171**	**176**
C. Waste Incineration		**IE**	**24**	**28**	**26**	**26**	**32**	**32**	**32**	**32**	**32**	**32**	**32**	**32**	**32**	**32**
D. Other	NO															
7. Other	NO															
Memo Items (not included above):																
International Bunkers		**4904**	**4904**	**7049**	**6741**	**5291**	**5858**	**5538**	**5538**	**5540**	**5542**	**5538**	**5916**	**6308**	**6416**	**6201**
Aviation		1755	1755	1888	2376	2603	2671	2349	2350	2352	2353	2348	2728	3119	3227	3013
Marine		3149	3149	5162	4365	2689	3187	3188	3188	3188	3188	3190	3188	3189	3189	3189
Multilateral Operations		**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**4641**	**4596**	**5582**	**6717**	**10340**	**NE**	**NE**	**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 11.2 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	52851	60905	53608	50844	50665	49472	45107	43766	45070	46816	43153	43713	42888	42163
1. Energy		51474	51543	59277	51785	49142	49212	48001	43593	42220	43455	45296	41477	42018	41037	40133
A. Fuel Combustion (Sectoral Approach)		51211	51243	58862	51122	48644	48836	47810	43377	41992	43228	45049	41293	41848	40867	39963
1. Energy Industries		26173	26215	32204	25572	22662	23553	23702	19231	18066	19337	20778	17570	18381	16677	14671
a Public Electricity and Heat Production		24736	24778	30098	23136	20133	21032	21145	16698	15523	16758	18231	14894	15445	13831	11825
b Petroleum Refining		897	897	1371	988	927	912	970	970	970	970	959	970	970	970	970
c Manufacture of Solid Fuels and Other Energy Industries		540	540	735	1449	1602	1608	1586	1562	1573	1609	1588	1705	1965	1876	1876
2. Manufacturing Industries and Construction		5423	5424	5892	6012	5605	5199	4917	4942	4956	5004	5004	4961	4838	5008	5353
3. Transport		10336	10528	11852	12061	13052	13802	13058	13123	13028	13001	13202	13045	13092	13540	14195
a Civil Aviation		243	243	199	154	135	164	165	167	170	173	168	182	204	214	210
b Road Transport		9241	9275	10585	11202	12214	12948	12203	12267	12170	12141	12346	12176	12202	12640	13312
c Railways		297	297	303	228	232	237	237	237	237	237	237	237	237	237	237
d Navigation		555	714	766	476	471	453	453	452	452	451	452	450	450	450	436
4. Other Sectors		9159	8957	8663	7367	7054	6175	6025	5974	5836	5781	5958	5612	5433	5536	5638
a Commercial and Institutional		1403	1405	1132	893	939	818	846	856	847	844	843	844	842	869	903
b Residential		5084	5059	5106	4132	3933	3251	3017	2936	2785	2702	2938	2461	2157	2080	1816
c Agriculture/Forestry/Fisheries		2673	2493	2424	2341	2183	2105	2162	2182	2203	2234	2177	2307	2434	2587	2920
5. Other	(1)	119	119	252	111	271	108	108	107	106	105	107	105	105	105	105
B. Fugitive Emissions from Fuels		263	300	415	662	499	376	191	217	228	228	248	184	170	170	170
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	191	217	228	228	248	184	170	170	170
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	191	217	228	228	248	184	170	170	170
2. Industrial Processes		1101	1152	1497	1701	1604	1360	1360	1405	1438	1507	1414	1568	1587	1743	1922
A. Mineral Products		1072	1069	1405	1616	1544	1320	1321	1366	1399	1468	1375	1529	1548	1704	1883
1 Cement Production		882	882	1204	1385	1363	1155									
2 Lime Production		152	116	88	77	63	66									
3 Limestone and Dolomite Use		18	14	54	90	56	39									

4 Soda Ash Production and Use	NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO									
5 Asphalt Roofing	(<0,5)	0	0	0	0	0	0									
6 Road Paving with Asphalt		2	2	2	2	2	2									
7 Other	(2)	17	55	58	63	59	60									
B. Chemical Industry		**1**	**1**	**1**	**1**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
2 Nitric Acid Production																
5 Other	(3)	1	1	1	1	3	2	2	2	2	2	2	2	2	2	2
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**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
E. Production of Halocarbons and SF_6																
F. Consumption of Halocarbons and SF_6																
1. Refrigeration and Air Conditioning Equipment																
2 Foam Blowing																
3 Fire Extinguishers																
4 Aerosol/Metered Dose Inhalers																
8 Electrical Equipment																
9 Other																
C_3F_8	(4)															
SF_6	(5)															
G. Other			**50**	**49**	**40**	**38**	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**34**
3. Solvent and Other Product Use		**137**	**135**	**107**	**99**	**74**	**65**	**83**	**79**	**79**	**79**	**77**	**79**	**79**	**79**	**79**
A Paint Application		24	26	18	19	12	9	34	32	32	32	28	32	32	32	32
B Degreasing and Dry Cleaning		46	0	0	0	0	0	14	14	14	14	11	14	14	14	14
C Chemical Products, Manufacture and Processing		3	23	21	16	15	15	7	7	7	7	8	7	7	7	7
D Other		**64**	**86**	**68**	**63**	**47**	**41**	**28**	**26**	**26**	**26**	**30**	**26**	**26**	**26**	**26**
1 Use of N_2O for Anaesthesia																
5 Other	(6)	**64**	86	68	63	47	41	28	26	26	26	30	26	26	26	26
4. Agriculture																
A Enteric Fermentation																
1 Cattle																
Dairy Cattle																
Non-Dairy Cattle																
2 Buffalo																

3 Sheep																
4 Goats																
5 Camels and Llamas																
6 Horses																
7 Mules and Asses																
8 Swine																
9 Poultry	NE															
10 Other																
Fur farming	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															
6. Waste			**21**	**24**	**23**	**23**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**
A. Solid Waste Disposal on Land	NE															
B. Waste-water Handling																
C. Waste Incineration	IE		21	24	23	23	29	29	29	29	29	29	29	29	29	29
D. Other	NO															
7. Other	**NA**															
Memo Items (not included above):																
International Bunkers		**4823**	**4823**	**6928**	**6629**	**5210**	**5760**	**5435**	**5435**	**5435**	**5435**	**5435**	**5807**	**6192**	**6299**	**6088**
Aviation		1736	1736	1867	2350	2574	2642	2309	2309	2309	2309	2309	2681	3066	3173	2962
Marine		3087	3087	5061	4279	2636	3118	3126	3126	3126	3126	3126	3126	3126	3126	3126
Multilateral Operations		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
CO_2 Emissions from Biomass		**4641**	**4596**	**5582**	**6717**	**1034 0**										

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 11.3 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**	**5504**	**5729**	**5624**	**5455**	**5559**	**5578**	**5513**	**5438**	**5427**	**5500**	**5376**	**5416**	**5406**	**5384**
1. Energy		**222**	**228**	**516**	**643**	**638**	**580**	**687**	**578**	**509**	**504**	**572**	**467**	**528**	**518**	**500**
A. Fuel Combustion (Sectoral Approach)		**182**	**185**	**448**	**560**	**531**	**452**	**620**	**544**	**472**	**465**	**511**	**426**	**485**	**478**	**468**
1. Energy Industries		**23**	**23**	**249**	**321**	**269**	**183**	**339**	**264**	**194**	**188**	**233**	**152**	**214**	**210**	**201**
a Public Electricity and Heat Production		22	22	247	320	267	182	337	262	192	186	232	151	212	208	199
b Petroleum Refining		1	1	1	0	0	0	1	1	1	1	0	1	1	1	1
c Manufacture of Solid Fuels and Other Energy Industries		0	0	1	1	2	1	1	1	1	1	1	1	1	1	1
2. Manufacturing Industries and Construction		**15**	**15**	**18**	**33**	**26**	**21**	**25**	**25**	**25**	**25**	**24**	**24**	**23**	**24**	**25**
3. Transport		**53**	**56**	**51**	**40**	**30**	**23**	**18**	**16**	**15**	**14**	**17**	**11**	**8**	**7**	**6**
a Civil Aviation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b Road Transport		52	55	50	39	29	22	17	15	14	13	16	11	8	6	5
c Railways		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
d Navigation		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4. Other Sectors		**91**	**90**	**130**	**165**	**205**	**225**	**239**	**239**	**238**	**238**	**236**	**238**	**239**	**237**	**236**
a Commercial and Institutional		4	4	13	20	18	18	17	17	17	17	17	16	16	16	17
b Residential		68	67	89	98	147	183	197	197	197	196	194	194	191	186	181
c Agriculture/Forestry/Fisheries		20	20	28	48	40	24	24	25	25	25	25	27	33	35	38
5. Other	(1)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
B. Fugitive Emissions from Fuels		**40**	**43**	**67**	**83**	**107**	**128**	**67**	**34**	**37**	**38**	**61**	**42**	**42**	**40**	**32**
1. Solid Fuels		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2. Oil and Natural Gas		**40**	**43**	**67**	**83**	**107**	**128**	**67**	**34**	**37**	**38**	**61**	**42**	**42**	**40**	**32**
a Oil		32	33	48	72	97	121	62	29	32	33	56	37	38	36	29
b Natural Gas		6	9	18	10	9	6	5	5	5	5	5	5	4	3	3
c Flaring		2	2	1	1	1	1	0	0	0	0	0	0	0	0	0
2. Industrial Processes	NA, NO, NE															
A. Mineral Products																
1 Cement Production																
2 Lime Production																
3 Limestone and Dolomite Use																
4 Soda Ash Production and Use	NO															
5 Asphalt Roofing	(<0,5)															

6 Road Paving with Asphalt																
7 Other	(2)															
B. Chemical Industry																
2 Nitric Acid Production																
5 Other	(3)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C. Metal Production																
1 Iron and Steel Production		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4 SF_6 Used in Aluminium and Magnesium Foundries																
D. Other Production		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
E. Production of Halocarbons and SF_6																
F. Consumption of Halocarbons and SF_6																
1. Refrigeration and Air Conditioning Equipment																
2 Foam Blowing																
3 Fire Extinguishers																
4 Aerosol/Metered Dose Inhalers																
8 Electrical Equipment																
9 Other																
C_3F_8	(4)															
SF_6	(5)															
G. Other		**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
3. Solvent and Other Product Use																
A Paint Application																
B Degreasing and Dry Cleaning																
C Chemical Products, Manufacture and Processing																
D Other																
1 Use of N_2O for Anaesthesia																
5 Other	(6)															
4. Agriculture		**4011**	**4132**	**4070**	**3865**	**3749**	**3872**	**3751**	**3796**	**3790**	**3784**	**3796**	**3766**	**3737**	**3728**	**3719**
A Enteric Fermentation		**3259**	**3261**	**3135**	**2876**	**2724**	**2819**	**2702**	**2738**	**2710**	**2683**	**2730**	**2600**	**2462**	**2498**	**2535**
1 Cattle		**2950**	**2950**	**2787**	**2486**	**2298**	**2382**									
Dairy Cattle		1844	1844	1762	1564	1518	1528									
Non-Dairy Cattle		1106	1106	1025	921	780	854									
2 Buffalo		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3 Sheep		33	33	29	40	46	42									
4 Goats		2	2	2	2	3	4									

5 Camels and Llamas		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
6 Horses		60	60	64	67	78	87									
7 Mules and Asses		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
8 Swine		213	213	250	278	297	302									
9 Poultry	NE	NE	NE	NE	NE	NE	NE									
10 Other		**NE**	**2**	**2**	**2**	**2**	**2**									
Fur farming	NE	NE	2	2	2	2	2									
B. Manure Management		**752**	**869**	**933**	**986**	**1021**	**1050**	**1046**	**1055**	**1077**	**1099**	**1065**	**1164**	**1273**	**1227**	**1182**
1 Cattle		**282**	**497**	**466**	**447**	**434**	**429**									
Dairy Cattle		213	346	335	332	346	338									
Non-Dairy Cattle		69	151	131	115	88	91									
2 Buffalo	NO	NO	NO	NO	NO	NO	NO									
3 Sheep		1	1	1	1	1	1									
4 Goats		0	0	0	0	0	0									
5 Camels and Llamas	NO	NO	NO	NO	NO	NO	NO									
6 Horses		4	9	9	10	12	12									
7 Mules and Asses	NO	NO	NO	NO	NO	NO	NO									
8 Swine		448	323	421	485	521	541									
9 Poultry		6	10	11	11	10	13									
10 Other livestock		**9**	**28**	**24**	**32**	**42**	**54**									
Fur farming		9	28	24	32	42	54									
11 Anaerobic Lagoons																
12 Liquid Systems																
13 Solid Storage and Dry Lot																
14 Other AWMS																
C. Rice Cultivation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural Soils																
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	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Field Burning of Agricultural Residues	NO	NO	**2**	**2**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
G. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

6. Waste		**1460**	**1144**	**1144**	**1116**	**1069**	**1107**	**1140**	**1139**	**1139**	**1139**	**1133**	**1142**	**1151**	**1159**	**1165**
A. Solid Waste Disposal on Land		1334	1111	1104	1069	1019	1057	1089	1088	1088	1088	1082	1091	1099	1108	1113
B. Waste-water Handling		126	30	37	45	47	47	47	47	48	48	47	48	48	48	49
C. Waste Incineration		IE	3	3	3	3	3	3	3	3	3	3	3	3	3	3
D. Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
7. Other		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items (not included above):																
International Bunkers		**2**	**2**	**3**	**3**	**2**	**3**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Aviation		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Marine		1	1	2	2	1	2	2	2	2	2	2	2	2	2	2
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 11.4 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**	**10523**	**9380**	**8379**	**6689**	**6724**	**6704**	**6692**	**6647**	**6594**	**6672**	**6432**	**6172**	**6194**	**6214**
1. Energy		**425**	**396**	**460**	**449**	**435**	**438**	**420**	**418**	**423**	**420**	**424**	**408**	**400**	**407**	**416**
A. Fuel Combustion (Sectoral Approach)		**424**	**396**	**459**	**448**	**434**	**437**	**419**	**416**	**422**	**419**	**423**	**407**	**399**	**406**	**415**
1. Energy Industries		**119**	**119**	**150**	**145**	**132**	**133**	**124**	**121**	**127**	**123**	**126**	**117**	**111**	**110**	**107**
a Public Electricity and Heat Production		103	103	127	117	102	103	105	102	107	103	104	96	90	89	85
b Petroleum Refining		9	9	15	11	11	11	11	11	11	11	11	11	11	11	11
c Manufacture of Solid Fuels and Other Energy Industries		6	6	9	17	19	19	8	9	9	9	11	10	11	11	11
2. Manufacturing Industries and Construction		**54**	**54**	**57**	**60**	**57**	**57**	**51**	**51**	**52**	**52**	**53**	**52**	**51**	**52**	**55**
3. Transport		**141**	**116**	**149**	**151**	**141**	**138**	**133**	**132**	**132**	**133**	**134**	**128**	**126**	**131**	**138**
a Civil Aviation		3	3	3	2	3	3	2	2	2	2	2	2	2	2	2
b Road Transport		125	97	129	138	128	126	121	120	121	121	122	116	113	119	126
c Railways		3	3	3	2	2	2	2	2	2	2	2	2	2	2	2
d Navigation		10	13	14	8	8	8	8	8	8	8	8	8	8	8	8
4. Other Sectors		**109**	**105**	**101**	**91**	**102**	**108**	**110**	**110**	**110**	**110**	**109**	**109**	**110**	**112**	**113**
a Commercial and Institutional		12	12	10	8	8	7	8	8	8	8	8	8	8	8	8
b Residential		57	57	57	51	63	70	70	70	69	68	70	67	64	63	60
c Agriculture/Forestry/Fisheries		40	36	34	32	31	31	32	33	33	33	32	35	39	41	45
5. Other	(1)	**1**	**1**	**2**	**1**	**3**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
B. Fugitive Emissions from Fuels		**1**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
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**	**1**	**1**	**1**	**1**	**1**	**1**
a Oil		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b Natural Gas		NA,NO	NA	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
c Flaring		1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
2. Industrial Processes	NA, NO	**1043**	**1043**	**904**	**1004**	**NO, NA**	**NO, NA**	**NO, NA**	**NO, NA**	**NO, NA**	**NO, NA**	**NO, NA**	**NO, NA**	**NO, NA**	**NO, NA**	**NO, NA**
A. Mineral Products		IE, NA	IE, NA	IE, NA	IE, NA	IE, NA										
1 Cement Production																
2 Lime Production																
3 Limestone and Dolomite Use																
4 Soda Ash Production and Use	NO															

5 Asphalt Roofing	(<0, 5)															
6 Road Paving with Asphalt																
7 Other	(2)															
B. Chemical Industry		**1043**	**1043**	**904**	**1004**	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA
2 Nitric Acid Production		1043	1043	904	1004	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5 Other	(3)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C. Metal Production		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1 Iron and Steel Production		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4 SF_6 Used in Aluminium and Magnesium Foundries																
D. Other Production		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
E. Production of Halocarbons and SF_6																
F. Consumption of Halocarbons and SF_6																
1. Refrigeration and Air Conditioning Equipment																
2 Foam Blowing																
3 Fire Extinguishers																
4 Aerosol/Metered Dose Inhalers																
8 Electrical Equipment																
9 Other																
C_3F_8	(4)															
SF_6	(5)															
G. Other		**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
3. Solvent and Other Product Use		**NA**	**NA**	**NA**	**NA**	**14**	**27**	**27**	**27**	**27**	**27**	**27**	**27**	**27**	**27**	**27**
A Paint Application		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B Degreasing and Dry Cleaning		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C Chemical Products, Manufacture and Processing		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D Other		NA	NA	NA	NA	**14**	**27**	**27**	**27**	**27**	**27**	**27**	**27**	**27**	**27**	**27**
1 Use of N_2O for Anaesthesia		NA	NE	NE	NE	14	27	27	27	27	27	27	27	27	27	27
5 Other	(6)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4. Agriculture		**9037**	**8977**	**7905**	**6833**	**6153**	**6154**	**6152**	**6140**	**6089**	**6038**	**6114**	**5884**	**5628**	**5636**	**5643**
A Enteric Fermentation																
1 Cattle																
Dairy Cattle																
Non-Dairy Cattle																
2 Buffalo																

3 Sheep																
4 Goats																
5 Camels and Llamas																
6 Horses																
7 Mules and Asses																
8 Swine																
9 Poultry	NE															
10 Other																
Fur farming	NE															
B. Manure Management		**685**	**667**	**622**	**582**	**566**	**505**	**580**	**584**	**577**	**570**	**563**	**548**	**512**	**513**	**513**
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	NO	NO	NO	NO	NO									
12 Liquid Systems		96	89	78	75	74	75									
13 Solid Storage and Dry Lot		589	577	544	507	492	431									
14 Other AWMS		NO	NO	NO	NO	NO	NO									
C. Rice Cultivation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural Soils		**8352**	**8309**	**7282**	**6250**	**5585**	**5647**	**5571**	**5555**	**5511**	**5467**	**5550**	**5335**	**5115**	**5122**	**5130**
1 Direct Soil Emissions		4225	4220	3638	3252	3071	3154									
2 Pasture, Range and Paddock Manure		312	314	325	314	239	214									
3 Indirect Emissions		3787	3775	3318	2684	2276	2279									
4 Other		**28**	**IE**	**IE**	**IE**	**IE**	**IE**									
Industrial waste used as fertilizer		9	IE	IE	IE	IE	IE									
Use of sewage sludge as fertilizers		19	IE	IE	IE	IE	IE									
E. Prescribed Burning of Savannas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

F. Field Burning of Agricultural Residues	NO	NO	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
G. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
6. Waste		**88**	**106**	**111**	**93**	**87**	**105**	**105**	**107**	**108**	**109**	**107**	**113**	**118**	**123**	**127**
A. Solid Waste Disposal on Land		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B. Waste-water Handling		88	106	110	93	87	105	105	106	108	109	107	112	118	123	127
C. Waste Incineration		IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
7. Other		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items (not included above):																
International Bunkers		**78**	**78**	**119**	**109**	**79**	**95**	**100**	**101**	**102**	**104**	**100**	**106**	**113**	**114**	**111**
Aviation		18	18	20	25	28	28	39	40	41	43	38	45	52	54	50
Marine		60	60	99	83	51	67	61	61	61	61	62	61	61	61	61
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 11.5 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**	**830**	**804**	**756**	**692**	**787**	**488**	**152**	**152**	**152**
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	(1)															
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**	**830**	**804**	**756**	**692**	**787**	**488**	**152**	**152**	**152**
A. Mineral Products																
1 Cement Production																
2 Lime Production																
3 Limestone and Dolomite Use																
4 Soda Ash Production and Use	NO															
5 Asphalt Roofing	(<0,5)															
6 Road Paving with Asphalt																
7 Other	(2)															

B. Chemical Industry																
2 Nitric Acid Production																
5 Other	(3)															
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**	**830**	**804**	**756**	**692**	**787**	**488**	**152**	**152**	**152**
1. Refrigeration and Air Conditioning Equipment		35		35	420	663	730									
2 Foam Blowing		183		183	168	119	103									
3 Fire Extinguishers		NO		NO	NO	NO	NO									
4 Aerosol/Metered Dose Inhalers		NA		NA,NO	19	21	19									
8 Electrical Equipment		NA		NA	NA	NO	NO									
9 Other		NO		NO	NO	NO	1									
C_3F_8	(4)															
SF_6	(5)															
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	(6)															
4. Agriculture																
A Enteric Fermentation																
1 Cattle																
Dairy Cattle																
Non-Dairy Cattle																
2 Buffalo																
3 Sheep																
4 Goats																
5 Camels and Llamas																
6 Horses																

7 Mules and Asses																
8 Swine																
9 Poultry	NE															
10 Other																
Fur farming	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															
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 11.6 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**	**11**	**10**	**10**	**9**	**10**	**7**	**6**	**6**	**6**
1. Energy																
A. Fuel Combustion (Sectoral Approach)																
1. Energy Industries																
a Public Electricity and Heat Production																
b Petroleum Refining																
c Manufacture of Solid Fuels and Other Energy Industries																
2. Manufacturing Industries and Construction																
3. Transport																
a Civil Aviation																
b Road Transport																
c Railways																
d Navigation																
4. Other Sectors																
a Commercial and Institutional																
b Residential																
c Agriculture/Forestry/Fisheries																
5. Other	(1)															
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**	**11**	**10**	**10**	**9**	**10**	**7**	**6**	**6**	**6**
A. Mineral Products																
1 Cement Production																
2 Lime Production																
3 Limestone and Dolomite Use																
4 Soda Ash Production and Use	NO															
5 Asphalt Roofing	(<0,5)															

6 Road Paving with Asphalt																
7 Other	(2)															
B. Chemical Industry																
2 Nitric Acid Production																
5 Other	(3)															
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		**1**		**1**	**18**	**14**	**13**	**11**	**10**	**10**	**9**	**10**	**7**	**6**	**6**	**6**
1. Refrigeration and Air Conditioning Equipment		1		1	16	14	9	8	7	6	6	7	4	2	2	2
2 Foam Blowing		NA		NA	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3 Fire Extinguishers		NO		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4 Aerosol/Metered Dose Inhalers		NA		NA	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
8 Electrical Equipment		NA		NA	0	0	0	3	3	3	3	3	3	3	3	3
9 Other		**NA,NO**		**NO**	**2**	**NA,NO**	**4**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
C_3F_8	(4)	NA,NO		NO	2	NA,NO	4	NO	NO	NO	NO	NO	NO	NO	NO	NO
SF_6	(5)															
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	(6)															
4. Agriculture																
A Enteric Fermentation																
1 Cattle																
Dairy Cattle																
Non-Dairy Cattle																
2 Buffalo																
3 Sheep																
4 Goats																

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

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 Appli-cable

IE: Included elsewhere

Table 11.7 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**	**36**	**36**	**69**	**115**	**58**	**123**	**59**	**59**	**59**
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	(1)															
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**	**36**	**36**	**69**	**115**	**58**	**123**	**59**	**59**	**59**
A. Mineral Products																
1 Cement Production																
2 Lime Production																
3 Limestone and Dolomite Use																
4 Soda Ash Production and Use	NO															
5 Asphalt Roofing	(<0,5)															

6 Road Paving with Asphalt																
7 Other	(2)															
B. Chemical Industry																
2 Nitric Acid Production																
5 Other	(3)															
C. Metal Production		**36**		**36**	**21**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
1 Iron and Steel Production																
4 SF_6 Used in Aluminium and Magnesium Foundries		36		36	21	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
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		**71**		**71**	**38**	**22**	**32**	**36**	**36**	**69**	**115**	**58**	**123**	**59**	**59**	**59**
1. Refrigeration and Air Conditioning Equipment		0		NA	NA	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2 Foam Blowing		NA		NA	NA	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3 Fire Extinguishers		NO		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4 Aerosol/Metered Dose Inhalers		NA		NA	NA	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
8 Electrical Equipment		4		4	11	13	16	13	13	14	14	14	15	16	16	16
9 Other		**68**		**68**	**27**	**9**	**15**	**23**	**23**	**56**	**101**	**44**	**108**	**43**	**43**	**43**
C_3F_8	(4)															
SF_6	(5)	68		68	27	9	15	23	23	56	101	44	108	43	43	43
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	(6)															
4. Agriculture																
A Enteric Fermentation																
1 Cattle																
Dairy Cattle																
Non-Dairy Cattle																
2 Buffalo																
3 Sheep																
4 Goats																

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

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	(4): PFC used as detergent
(2): Glass production, production of bricks and clay products	(5): Window plate production, research laboratories and running shoes
(3): Catalysts/Fertilizers, Pesticides and Sulphuric acid	(6): Other products, manufacture and processing such as vessels, vehicles, wood, food and graphic
NO: Not occurring	NA: Not Appli-cable
NE: Not estimated	IE: Included elsewhere

Table 11.8 Historic and projected greenhouse gas (GHG) emissions in ktonnes CO_2 equivalents.

GHG emissions and projections (Gg CO2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025
Denmark's total emissions excluding net emissions from LULUCF		**69323,336**	**68969**	**76227**	**67953**	**63554**	**70574**	**66711**	**65246**	**65844**	**62779**	**66231**	**60517**	**55189**	**54660**
1. Energy		**52121**	**52083**	**59911**	**52368**	**49629**	**56574**	**52713**	**51248**	**51920**	**48941**	**52279**	**47051**	**42421**	**41895**
A. Fuel Combustion (Sectoral Approach)		**51817**	**51779**	**59485**	**51692**	**49091**	**56080**	**52198**	**50768**	**51442**	**48462**	**51790**	**46569**	**41953**	**41556**
1. Energy Industries		**26315**	**26315**	**32337**	**25585**	**22556**	**29169**	**25212**	**24543**	**25382**	**22549**	**25371**	**21179**	**17254**	**16443**
a Public Electricity and Heat Production		24861	24861	30206	23119	19991	26390	22389	21619	22343	19402	22429	17844	13567	12934
b Petroleum Refining		908	908	1387	999	942	949	949	949	949	949	949	949	949	949
c Manufacture of Solid Fuels and Other Energy Industries		546	546	744	1467	1623	1829	1874	1975	2089	2198	1993	2385	2738	2559
2. Manufacturing Industries and Construction		**5493**	**5493**	**5965**	**6100**	**5690**	**5782**	**5784**	**5779**	**5745**	**5719**	**5762**	**5507**	**5274**	**5257**
3. Transport		**10529**	**10700**	**12051**	**12240**	**13225**	**13846**	**14083**	**13528**	**13608**	**13688**	**13751**	**13902**	**14040**	**14849**
a Civil Aviation		246	246	202	157	136	163	164	164	164	165	164	172	185	196
b Road Transport		9418	9427	10763	11379	12384	12993	13229	12674	12754	12832	12896	13036	13148	13928
c Railways		300	300	306	230	234	228	229	230	231	231	230	236	249	267
d Navigation		566	727	780	475	471	462	461	460	460	459	460	458	458	458
4. Other Sectors		**9359**	**9150**	**8878**	**7655**	**7347**	**7129**	**6965**	**6763**	**6552**	**6351**	**6752**	**5826**	**5230**	**4853**
a Commercial and Institutional		1419	1419	1139	941	940	972	965	932	870	828	914	705	682	678
b Residential		5208	5183	5253	4282	4144	3813	3645	3472	3312	3137	3476	2729	2137	1732
c Agriculture/Forestry/Fisheries		2732	2549	2486	2433	2263	2343	2354	2358	2369	2386	2362	2392	2412	2443
5. Other	(1)	**120**	**120**	**254**	**112**	**274**	**155**	**155**	**155**	**155**	**155**	**155**	**155**	**155**	**155**
B. Fugitive Emissions from Fuels		**304**	**304**	**426**	**676**	**538**	**494**	**515**	**480**	**478**	**479**	**489**	**482**	**468**	**340**
1. Solid Fuels		**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2. Oil and Natural Gas		**304**	**304**	**426**	**676**	**538**	**494**	**515**	**480**	**478**	**479**	**489**	**482**	**468**	**340**
a Oil		32	32	48	73	93	66	62	29	32	33	45	37	38	36
b Natural Gas		6	6	12	5	5	5	5	5	5	5	5	5	4	3
c Flaring		267	267	367	598	439	423	448	445	442	441	440	441	426	300
2. Industrial Processes		**2470**	**2145**	**2675**	**3367**	**2500**	**2615**	**2587**	**2561**	**2546**	**2519**	**2566**	**2322**	**1913**	**1915**
A. Mineral Products		**1072**	**1073**	**1407**	**1641**	**1641**	**1673**	**1663**	**1663**	**1664**	**1656**	**1664**	**1657**	**1649**	**1650**
1 Cement Production		882	882	1204	1406	1456	0	0	0	0	0	0	0	0	0
2 Lime Production		152	116	88	77	63	0	0	0	0	0	0	0	0	0
3 Limestone and Dolomite Use		18	18	55	94	61	0	0	0	0	0	0	0	0	0
4 Soda Ash Production and Use	NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 Asphalt Roofing	(<0,5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 Road Paving with Asphalt		2	2	2	2	2	0	0	0	0	0	0	0	0	0

7 Other	(2)	17	55	58	63	59	0	0	0	0	0	0	0	0	0
B. Chemical Industry		**1044**	**1044**	**905**	**1004**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
2 Nitric Acid Production		1043	1043	904	1004	0	0	0	0	0	0	0	0	0	0
5 Other	(3)	1	1	1	1	3	2	2	2	2	2	2	2	2	2
C. Metal Production		**64**	**28**	**74**	**62**	**16**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**
1 Iron and Steel Production		28	28	39	41	16	45	45	45	45	45	45	45	45	45
4 SF_6 Used in Aluminium and Magnesium Foundries		36	0	36	21	0	0	0	0	0	0	0	0	0	0
D. Other Production		**NE, NA**	**NE, NA**	**NE, NA**	**NE, NA**	**NE, NA**	**NE, NA**	**NE, NA**	**NE, NA**	**NE, NA**	**NE, NA**	**NE, NA**	**NE, NA**	**NE, NA**	**NE, NA**
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		**290**	**0**	**290**	**660**	**841**	**895**	**877**	**851**	**835**	**816**	**855**	**619**	**217**	**217**
1. Refrigeration and Air Conditioning Equipment		36	0	36	436	664	9	8	7	6	6	7	4	2	2
2 Foam Blowing		183	0	183	168	146	0	0	0	0	0	0	0	0	0
3 Fire Extinguishers		0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 Aerosol/Metered Dose Inhalers		0	0	0	17	9	0	0	0	0	0	0	0	0	0
8 Electrical Equipment		4	0	4	11	13	16	17	17	17	17	17	18	20	20
9 Other		**68**	**0**	**68**	**29**	**9**	**23**	**23**	**23**	**56**	**101**	**45**	**108**	**43**	**43**
C_3F_8	(4)	0	0	0	2	0	0	0	0	0	0	0	0	0	0
SF_6	(5)	68	0	68	27	9	23	23	23	56	101	45	108	43	43
G. Other		**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
3. Solvent and Other Product Use		**137**	**148**	**139**	**113**	**117**	**124**	**120**	**117**	**117**	**117**	**119**	**117**	**117**	**117**
A Paint Application		24	61	50	48	41	35	34	32	32	32	33	32	32	32
B Degreasing and Dry Cleaning		46	25	21	21	17	15	14	14	14	14	14	14	14	14
C Chemical Products, Manufacture and Processing		3	10	11	9	10	7	7	7	7	7	7	7	7	7
D Other		**64**	**52**	**56**	**35**	**49**	**66**	**65**	**64**	**64**	**64**	**64**	**64**	**64**	**64**
1 Use of N_2O for Anaesthesia		0	0	0	0	14	37	37	37	37	37	37	37	37	37
5 Other	(6)	64	52	56	35	35	29	28	26	26	26	27	26	26	26
4. Agriculture		**13048**	**13044**	**11938**	**10607**	**9952**	**9866**	**9899**	**9932**	**9875**	**9818**	**9878**	**9647**	**9361**	**9361**
A Enteric Fermentation		**3259**	**3259**	**3116**	**2862**	**2661**	**2667**	**2702**	**2738**	**2710**	**2683**	**2700**	**2600**	**2462**	**2498**
1 Cattle		**2950**	**2950**	**2770**	**2484**	**2256**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Dairy Cattle		1844	1844	1762	1564	1518	0	0	0	0	0	0	0	0	0
Non-Dairy Cattle		1106	1106	1008	920	738	0	0	0	0	0	0	0	0	0
2 Buffalo		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3 Sheep		33	33	29	29	34	0	0	0	0	0	0	0	0	0
4 Goats		2	2	3	3	4	0	0	0	0	0	0	0	0	0

5 Camels and Llamas		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
6 Horses		60	60	64	67	70	0	0	0	0	0	0	0	0	0
7 Mules and Asses		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
8 Swine		213	213	250	278	297	0	0	0	0	0	0	0	0	0
9 Poultry	NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10 Other		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fur farming	NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B. Manure Management		**1437**	**1436**	**1513**	**1556**	**1583**	**1612**	**1626**	**1639**	**1654**	**1669**	**1640**	**1712**	**1785**	**1740**
1 Cattle		**282**	**282**	**268**	**260**	**261**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Dairy Cattle		213	213	216	214	225	0	0	0	0	0	0	0	0	0
Non-Dairy Cattle		69	69	52	45	36	0	0	0	0	0	0	0	0	0
2 Buffalo	NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 Sheep		1	1	1	1	1	0	0	0	0	0	0	0	0	0
4 Goats		0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 Camels and Llamas	NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 Horses		4	4	5	5	5	0	0	0	0	0	0	0	0	0
7 Mules and Asses	NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 Swine		448	448	578	667	720	0	0	0	0	0	0	0	0	0
9 Poultry		6	6	7	6	6	0	0	0	0	0	0	0	0	0
10 Other livestock		**9**	**9**	**9**	**16**	**31**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fur farming		9	9	9	16	31	0	0	0	0	0	0	0	0	0
11 Anaerobic Lagoons		0	0	0	0	0	0	0	0	0	0	0	0	0	0
12 Liquid Systems		96	95	84	80	77	0	0	0	0	0	0	0	0	0
13 Solid Storage and Dry Lot		589	590	562	522	481	0	0	0	0	0	0	0	0	0
14 Other AWMS		0	0	0	0	0	0	0	0	0	0	0	0	0	0
C. Rice Cultivation	NO	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
D. Agricultural Soils		**8352**	**8349**	**7309**	**6190**	**5709**	**5587**	**5571**	**5555**	**5511**	**5467**	**5538**	**5335**	**5115**	**5122**
1 Direct Soil Emissions		4225	4222	3617	3235	2986	0	0	0	0	0	0	0	0	0
2 Pasture, Range and Paddock Manure		312	312	324	307	282	0	0	0	0	0	0	0	0	0
3 Indirect Emissions		3787	3787	3314	2595	2361	0	0	0	0	0	0	0	0	0
4 Other		**28**	**28**	**55**	**53**	**79**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Industrial waste used as fertilizer		9	9	27	31	61	0	0	0	0	0	0	0	0	0
Use of sewage sludge as fertilizers		19	19	28	22	18	0	0	0	0	0	0	0	0	0
E. Prescribed Burning of Savannas	NO	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
F. Field Burning of Agricultural Residues	NO	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
G. Other	NO	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

6. Waste		**1547**	**1548**	**1563**	**1498**	**1355**	**1395**	**1392**	**1388**	**1386**	**1384**	**1389**	**1379**	**1376**	**1373**
A. Solid Waste Disposal on Land		**1334**	**1335**	**1301**	**1215**	**1043**	**1090**	**1089**	**1088**	**1088**	**1088**	**1089**	**1091**	**1099**	**1108**
B. Waste-water Handling		**213**	**213**	**262**	**283**	**312**	**305**	**302**	**300**	**298**	**295**	**300**	**288**	**277**	**265**
C. Waste Incineration		**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**
D. Other		**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
7. Other		**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Memo Items (not included above):															
International Bunkers		**4904**	**4904**	**7049**	**6741**	**5293**	**6153**	**6155**	**6144**	**6125**	**6152**	**6048**	**6282**	**6524**	**6724**
Aviation		1755	1755	1888	2376	2604	2640	2643	2632	2613	2640	2605	2770	3012	3212
Marine		3149	3149	5162	4365	2689	3512	3512	3512	3512	3512	3443	3512	3512	3512
Multilateral Operations		**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**4641**	**4641**	**5869**	**7169**	**10908**	**NE**	**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 11.9 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 %	76.7 %	79.8 %	78.5 %	79.7 %	79.4 %	79.0 %	77.6 %	77.2 %	77.8 %	78.2 %	77.6 %	78.7 %	78.4 %	78.1 %
CH_4	8.2 %	8.0 %	7.5 %	8.2 %	8.5 %	8.7 %	8.9 %	9.5 %	9.6 %	9.4 %	9.2 %	9.7 %	9.8 %	9.9 %	10.0 %
N_2O	15.3 %	15.3 %	12.3 %	12.3 %	10.5 %	10.5 %	10.7 %	11.5 %	11.7 %	11.4 %	11.1 %	11.6 %	11.1 %	11.3 %	11.5 %
HFCs	0.3 %	NA	0.3 %	0.9 %	1.3 %	1.3 %	1.3 %	1.4 %	1.3 %	1.2 %	1.3 %	0.9 %	0.3 %	0.3 %	0.3 %
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 %	0.1 %	0.1 %
Total	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**
Industrial gases (HFCs+PFCs+SF6)	0.5 %	NA	0.4 %	1.0 %	1.3 %	1.4 %	1.4 %	1.5 %	1.5 %	1.4 %	1.4 %	1.1 %	0.4 %	0.4 %	0.4 %
Trends relative to the KP base year 1990/95:															
CO_2	100	100	116	102	96	96	94	86	83	86	89	82	83	81	80
CH_4	100	97	101	99	96	98	98	97	96	95	97	94	95	95	95
N_2O	100	99	89	79	63	63	63	63	63	62	63	61	58	58	59
HFCs	100	NA	100	279	368	392	381	369	347	318	361	224	70	70	70
PFCs	100	NA	100	3563	2768	2547	2230	2051	1906	1778	1953	1473	1145	1145	1145
SF_6	100	NA	100	55	20	29	33	34	65	108	54	115	55	55	55
Total	**100**	**99**	**110**	**99**	**92**	**92**	**90**	**84**	**82**	**84**	**86**	**80**	**80**	**79**	**78**
Industrial gases (HFCs+PFCs+SF6)	100	NA	100	210	257	276	269	261	256	251	262	190	67	67	67
Distribution by IPCC main sector categories:															
Energy	75.2 %	75.7 %	78.9 %	77.4 %	78.7 %	78.7 %	78.4 %	76.7 %	76.1 %	76.6 %	77.4 %	76.2 %	77.4 %	76.7 %	76.0 %
Industrial Processes	3.6 %	3.2 %	3.6 %	5.0 %	3.8 %	3.5 %	3.6 %	3.9 %	4.0 %	4.0 %	3.8 %	3.9 %	3.2 %	3.6 %	4.0 %
Solvent and Other Product Use	0.2 %	0.2 %	0.1 %	0.1 %	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 %	19.0 %	15.7 %	15.7 %	15.5 %	15.7 %	15.8 %	17.1 %	17.4 %	17.0 %	16.6 %	17.4 %	16.9 %	17.1 %	17.3 %
Waste	2.2 %	1.8 %	1.7 %	1.8 %	1.8 %	1.9 %	2.0 %	2.2 %	2.2 %	2.2 %	2.1 %	2.3 %	2.3 %	2.4 %	2.4 %
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	116	101	96	96	94	86	83	85	89	81	82	81	79
Industrial Processes	100	89	110	137	99	91	91	91	92	94	92	89	73	79	87
Solvent and Other Product Use	100	99	78	72	65	67	81	78	78	78	76	78	78	78	78
Agriculture	100	100	92	82	76	77	76	76	76	75	76	74	72	72	72
Waste	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Total	**100**	**99**	**110**	**99**	**92**	**92**	**90**	**84**	**82**	**84**	**86**	**80**	**80**	**79**	**78**
Economic sector categories* Gg COs eqv.:															
Energy	26 620	26 701	33 086	26 786	23 669	24 373	24 424	19 868	18 653	19 915	21 447	18 066	18 920	17 208	15 181

Transport	10 650	10 821	12 307	12 364	13 496	14 072	13 317	13 380	13 283	13 254	13 461	13 290	13 332	13 785	14 446
Agriculture, forestry, fisheries	15 780	15 658	14 461	13 119	12 155	12 185	12 121	12 175	12 140	12 114	12 145	12 020	11 870	12 027	12 366
Business	9518	9245	9955	10 512	9184	8470	8212	8262	8285	8380	8321	8199	7688	8045	8606
Domestic sector	5208	5183	5253	4282	4143	3504	3284	3203	3050	2967	3202	2722	2411	2328	2057
Waste	1547	1271	1279	1233	1179	1241	1274	1274	1275	1277	1268	1283	1297	1311	1321
Total	**69 323**	**68 878**	**76 340**	**68 295**	**63 827**	**63 845**	**62 631**	**58 162**	**56 686**	**57 908**	**59 843**	**55 579**	**55 518**	**54 704**	**53 978**
Distribution by economic sector (%):															
Energy	38.4 %	38.8 %	43.3 %	39.2 %	37.1 %	38.2 %	39.0 %	34.2 %	32.9 %	34.4 %	35.8 %	32.5 %	34.1 %	31.5 %	28.1 %
Transport	15.4 %	15.7 %	16.1 %	18.1 %	21.1 %	22.0 %	21.3 %	23.0 %	23.4 %	22.9 %	22.5 %	23.9 %	24.0 %	25.2 %	26.8 %
Agriculture, forestry, fisheries	22.8 %	22.7 %	18.9 %	19.2 %	19.0 %	19.1 %	19.4 %	20.9 %	21.4 %	20.9 %	20.3 %	21.6 %	21.4 %	22.0 %	22.9 %
Business	13.7 %	13.4 %	13.0 %	15.4 %	14.4 %	13.3 %	13.1 %	14.2 %	14.6 %	14.5 %	13.9 %	14.8 %	13.8 %	14.7 %	15.9 %
Domestic sector	7.5 %	7.5 %	6.9 %	6.3 %	6.5 %	5.5 %	5.2 %	5.5 %	5.4 %	5.1 %	5.4 %	4.9 %	4.3 %	4.3 %	3.8 %
Waste	2.2 %	1.8 %	1.7 %	1.8 %	1.8 %	1.9 %	2.0 %	2.2 %	2.2 %	2.2 %	2.1 %	2.3 %	2.3 %	2.4 %	2.4 %
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	124	101	89	92	92	75	70	75	81	68	71	65	57
Transport	100	102	116	116	127	132	125	126	125	124	126	125	125	129	136
Agriculture, forestry, fisheries	100	99	92	83	77	77	77	77	77	77	77	76	75	76	78
Business	100	97	105	110	96	89	86	87	87	88	87	86	81	85	90
Domestic sector	100	100	101	82	80	67	63	61	59	57	61	52	46	45	39
Waste	100	82	83	80	76	80	82	82	82	83	82	83	84	85	85
Total	**100**	**99**	**110**	**99**	**92**	**92**	**90**	**84**	**82**	**84**	**86**	**80**	**80**	**79**	**78**

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PROJECTION OF GREENHOUSE GAS EMISSIONS 2009 TO 2030

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 basic scenarios together 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 the 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 plants. The projection models are based on the same structure and method as the Danish emission inventories in order to ensure consistency.

ISBN: 978-87-7073-188-1
ISSN: 1600-0048