National Environmental Research Institute
University of Aarhus · Denmark

NERI Technical Report No. 611, 2007

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Data sheet

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Abstract: 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 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 Authority. 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, PFs and SF_6

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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 emissions of policies and measures implemented until October 2006 ('with measures' projections).

The Department of Policy Analysis of the National Environmental Research Institute (NERI) has carried out the work. The project has been financed by the Danish Environment Protection Agency (EPA).

The steering committee of the project consisted of the following members:

Erik Rasmussen (chairman, EPA), Thomas C. Jensen, (The Danish Energy Agency), Jytte Boll Illerup, (project leader, NERI), Morten Winther (NERI) and Ole-Kenneth Nielsen (NERI).

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The Energy Agency for providing the energy consumption forecast.

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Risø National Laboratory, for providing the data on scenarios of the development of landfill deposited waste production.

The Danish Institute of Agricultural Science and the Danish Agricultural Advisory Centre for providing data for the agricultural sector.

Summary

This report contains a description of the models and background data used for projection of the greenhouse gases 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 emissions of policies and measures implemented until October 2006 ('with measures' projections). For activity rates, official Danish forecasts, e.g. the latest official forecast from the Danish Energy Authority, 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 expected to be Energy Industries (39%), Transport (21%), Agriculture (14%), and Other Sectors (10%). For the latter sector the most important sources are fuel use in the residential sector and the agricultural sector (Figure S.1). GHG emissions show a decreasing trend from 1990 to 2030 and, 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 67,800 ktonnes CO_2 equivalents and 60,386 ktonnes in 2030, corresponding to a decrease of about 10 %. From 1990 to '2010' the emissions are estimated to decrease by about 2%.

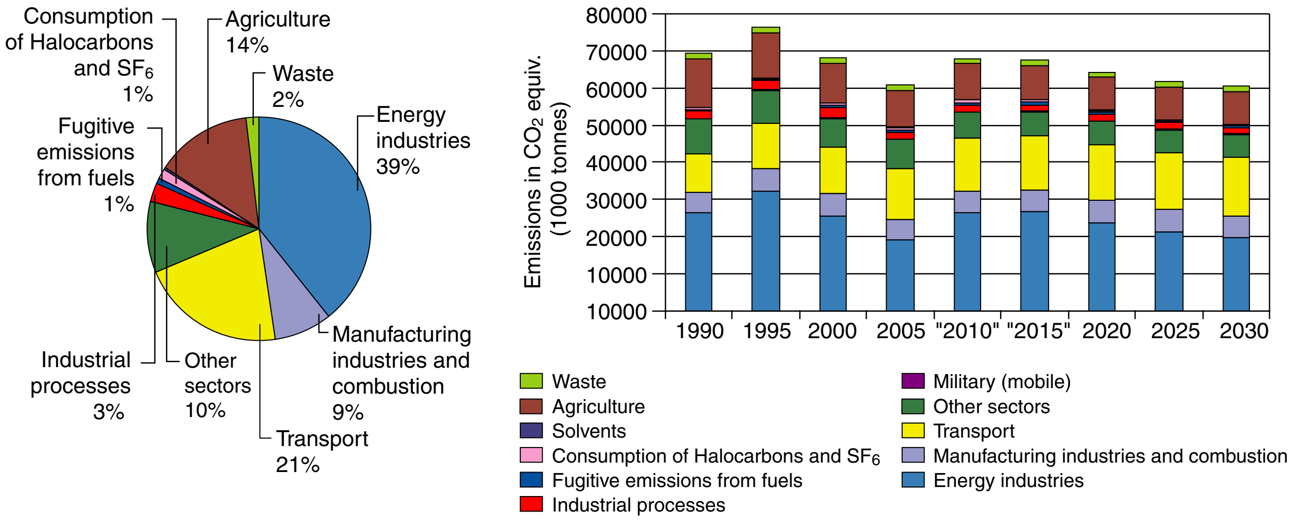


Figure S.1 Total GHG emissions in CO_2 equivalents. Distribution according to main sectors in '2010' (2008-2012) and time-series for 1990 to 2030.

Stationary combustion

The GHG emissions in '2010' from the main source, which is Public power (57%), are estimated to decrease significantly in the period from 2006 to 2030, due to a partial shift in fuel use from coal to wood and municipal waste. Also, for residential combustion plants a significant decrease in emissions is seen in the projection; the emissions almost halve from 1990 to 2030. The emissions from the other sectors remain almost constant over the period, except for energy use in oil and gas extraction where emissions are projected to increase by more than 300% from 1990 to '2010' and by almost 60% from '2010' to 2030.

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 1,750 ktonnes CO_2 equivalents. The most significant source is cement production, which contributes with more than 80% of the process-related GHG emissions. Most of the processes are assumed to be constant in the projection to 2030 at the same level as in 2004. 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 dependant on cement production also in the future.

Transport

Road transport is the main source of GHG emissions in '2010' and emissions from this sector are expected to increase by 59% from 1990 to 2030 due to growth in traffic. The emission shares for the remaining mobile sources are small compared with road transport, and from 1990 to 2030 the total share for these categories reduces from 32 to 20%. For agriculture/forestry/fisheries emissions reduce by 27% during the same period due to smaller numbers of agricultural tractors and harvesters though with larger engines. For industry (1A2f), the emissions increase by 4% from 1990-2030; for this sector there is an emission growth from 1990-2005 (due to increased activity), followed by a slight emission reduction from 2005-2030 due to machinery gradually becoming more fuel efficient. The latter explanation is also the reason for the small emission declines for the activities residential (gardening) (1A4b) and navigation (1A3d) during the forecast period.

Fluorinated gases

Over the period considered, the sum of F-gas emissions is predicted to reach a maximum in '2010' and then decrease considerably due to Danish regulation targeting the gases. HFCs are the dominant F-gases, and in '2010' they are expected to contribute with 78% of the F-gas emission.

Agriculture

From 1990 to 2004, the emission of greenhouse gases in the agricultural sector declined from 13,050 ktonnes CO_2 equivalents to 10,000 ktonnes CO_2 equivalents, which corresponds to a 23% reduction. This development is expected to continue, and the emission to 2030 is expected to fall further to 8,690 ktonnes CO_2 equivalents. The reduction both in the historical data and the projection can mainly be explained by improved utilisation of nitrogen in manure, a significant fall in the use of fertiliser and a reduced nitrogen leaching. These are consequences of active environmental policy measures in this area. Measures in the form of technologies to reduce ammonia emissions in the stable as well as expansion of biogas production are taken into account in the projections but do not contribute to significant changes in the total greenhouse gas emission.

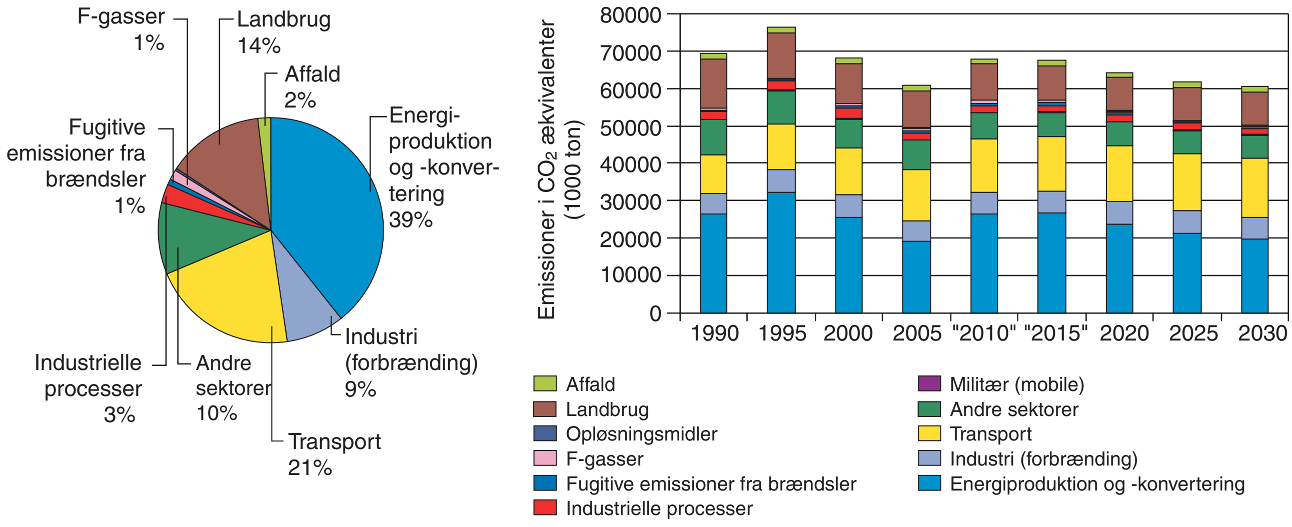
Waste (Landfill sites and wastewater treatment)

The total historical GHG emission from the waste sector has been decreasing since 1990, and this is predicted to continue until '2010'. This is mainly due to the decrease in the amount of waste deposited and, in turn, a decrease in the CH_4 emission from landfill. In '2010', CH_4 from landfill sites is predicted to contribute with 78% 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 or a slight decrease is predicted. A minor increase in the CH_4 emission from wastewater in the period considered is foreseen, while the N_2O emission from wastewater is forecasted to remain almost constant. This results in a minor increase in GHG for the sector as a whole after '2010'.

Sammenfatning

Denne rapport indeholder en beskrivelse af modeller og baggrundsdata anvendt til fremskrivning af de danske emissioner af drivhusgasser (CO_2, CH_4, N_2O, HFCer, PFCer, SF_6). Emissionerne er fremskrevet til 2030 på baggrund af et basisscenarium, som medtager de estimerede effekter på Danmarks drivhusgasudledninger af virkemidler iværksat indtil oktober 2006 ('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 (39 %), transport (21 %), landbrug (14 %), og andre sektorer (10 %). For den sidstnævnte sektor er de vigtigste kilder husholdninger og landbrug (Figur R.1). Drivhusgasemissionerne viser en faldende tendens fra 1990 to 2030, og generelt falder emissionsandelen for energisektoren mens emissionsandelen for transportsektoren stiger. De totale emissioner er beregnet til 67.800 ktons CO_2 ækvivalenter i '2010' og til 60.386 ktons i 2030 svarende til et fald på omkring 10 %. Fra 1990 til '2010' er emissionerne beregnet til at ville falde med ca. 2 %.



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' (57 %), er beregnet til at falde markant i perioden 2006 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 offshoresektoren, hvor emissioner fra anvendelse af energi til udvinding af olie og gas stiger med mere end 300 % fra 1990 til'2010' og med næsten 60 % fra '2010' til 2030.

Industri

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 1750 ktons CO_2-ekvivalenter. Den væsentligste kilde er cementproduktion, som bidrager med mere end 80 % af den procesrelaterede drivhusgasemission. De fleste procesemissioner er antaget at være konstante på samme niveau som 2004. Forbrug af kalk og derved emission af CO_2 fra røggasrensning antages at følge forbruget af kul og affald i kraftvarmeanlæg. Drivhusgasemissionen fra industri forventes også i fremtiden at være meget afhængig af cementproduktionen.

Transport

Vejtransport er den største emissionskilde for drivhusgasser i '2010', og fra 1990 til 2030 forventes emissionerne at stige med 59 % 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 32 til 20 %. For landbrug/skovbrug/fiskeri bliver emissionerne 27 % mindre i samme periode, hovedsageligt pga. et fald i antallet af traktorer og mejetærskere. For denne sektor stiger emissionerne fra 1990-2005 pga. øget aktivitet, hvorefter emissionerne falder en smule pga. gradvist mere energieffektive motorer. Dette er også grunden til de små emissionsfald for have-hushold (1A4b) og national søtransport i prognoseperioden.

F-gasser

I den betragtede periode er det forventet, at den samlede F-gasemission har maksimum i '2010' og derefter er stærkt faldende på grund af de danske reguleringer på området. Den dominerende F-gasgruppe er HFC'erne som i '2010' forventes at bidrage med 78 % til den samlede F-gas-emission.

Landbrug

I perioden fra 1990 til 2004 er emissionen af drivhusgasser faldet fra 13.050 ktons CO_2 ækvivalenter til 10.000 ktons CO_2 ækvivalenter, hvilket svarer til en reduktion på 23 %. Denne udvikling forventes at fortsætte og emissionen forudses at falde yderligere til 8.690 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 og 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 (lossepladser og spildvand rensningsanlæg)

Affaldssektorens samlede drivhusgasemissioner har i de historiske opgørelser 1990-2004 vist et stadigt fald og dette forventes at fortsætte til '2010'. Dette skyldes fald i de affaldsmængder, der deponeres, og dermed faldende CH_4 emissioner fra lossepladser. CH_4 fra lossepladser dominerer sektoren og forventes i '2010' at udgøre 78 % af sektorens emission. Fra '2010' forventes faldet i emissioner fra lossepladser at ophøre og blive nær konstant eller stige lidt. Der forventes en mindre stigning i CH_4 fra spildevand i perioden, mens N_2O fra spildevand forventes nærved konstant. Det samlede resultatet er en mindre stigning i drivhusgasemissionen for affaldssektoren efter '2010'.

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). The purpose of the present project, 'Projection of greenhouse gas emissions 2005 to 2030' has been to extend the models used in the projections to include the greenhouse gases CO_2, CH_4, N_2O as well as HFCs, PFCs and SF_6, and project the emissions for these gases to 2030.

1.1 Obligations

In relation to the Kyoto Protocol, for the period 2008-2012 the EU has committed itself to reduce emissions of greenhouse gases (GHGs) on average to 8% below the level in the so-called base year: 1990 for CO_2, methane, and nitrous oxide and either 1990 or 1995 for industrial greenhouse gases (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 greenhouse gases, 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 greenhouse gases. In this report the estimated effects of policies and measures implemented until October 2006 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).

This report is a background report to Denmark's Second National Allocation Plan (NAP2) under the EU Emissions Trading Scheme. NAP2

[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.

will include information on how Denmark will achieve its obligation with all the necessary measures in addition to the implemented measures taken into account in the present report's 'with measures' projection.

1.2 Greenhouse gases

The greenhouse gases 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 greenhouse gas 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 greenhouse gases methane and N_2O, which are very much linked to agricultural production, have increased by 150% and 16%, respectively (IPCC, Third Assessment Report). 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 greenhouse gases 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, methane is thus 21 times more powerful a greenhouse gas than CO_2, and N_2O is 310 times more powerful. Some of the other greenhouse gases (hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) have considerably higher global warming potential values. For example, sulphur hexafluoride has a global warming potential of 23,900 (IPCC, Second Assessment Report , 1996).

1.3 Historical emission data

The Danish greenhouse gas emissions are estimated according to the IPCC guidelines and are aggregated into seven main sectors (Illerup et al., 2006). The greenhouse gases include CO_2, CH_4, N_2O, HFCs, PFCs and SF_6. Figure 1.1 shows the estimated total greenhouse gas emissions in CO_2 equivalents from 1990 to 2004. The emissions are not corrected for electricity trade or temperature variations. CO_2 is the most important greenhouse gas, 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. The net CO_2 removal by forestry and soil (Land Use Change and Forestry (LUCF)) is in the region of 3% of the total emission in CO_2 equivalents in 2004. The national total greenhouse gas emission in CO_2 equivalents without LUCF has decreased by 1.5% from 1990 to 2004 and by 5.5% with LUCF.

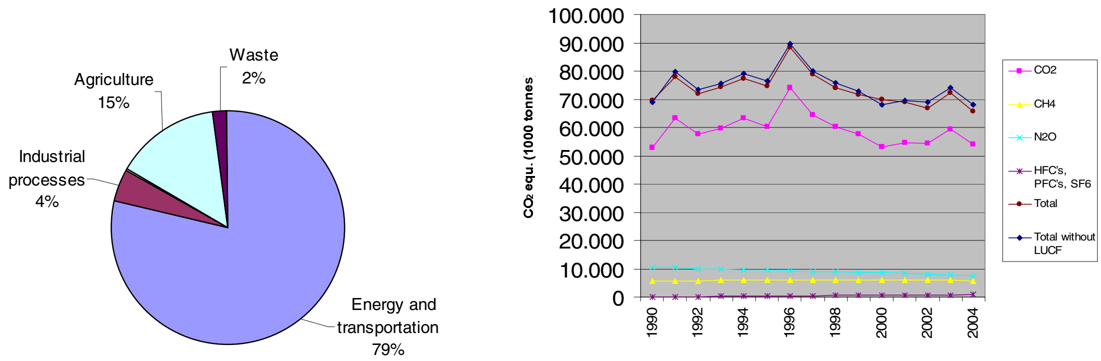


Figure 1.1 Greenhouse gas emissions in CO_2 equivalents distributed on main sectors for 2004. Left: Time-series for 1990 to 2004.

1.3.1 Carbon dioxide

The largest source for the emission of CO_2 is the energy sector, which includes combustion of fossil fuels such as oil, coal and natural gas (Figure 1.2). Public power and district heating plants contribute with almost half of the emissions. About 24% come from the transport sector. The CO_2 emission decreased by approx. 9% from 2003 to 2004. The reason for this decrease was mainly due to decreasing export of electricity. Also higher outdoor temperature in 2004 compared with 2003 contributed to the decrease. If the CO_2 emission is adjusted for climatic variations and electricity trade with other countries, then the CO_2 emission from the combustion of fossil fuels has decreased by 16% since 1990. The decrease in CO_2 emissions is observed despite almost constant gross energy consumption and an increase in the gross national product of 34%. This is due to changes in fuel from coal to natural gas and renewable energy. As a result of the lower consumption of coal in recent years, the main part of the CO_2 emission comes from oil combustion. In 2004, the actual CO_2 emission was about 2% higher than the emission in 1990.

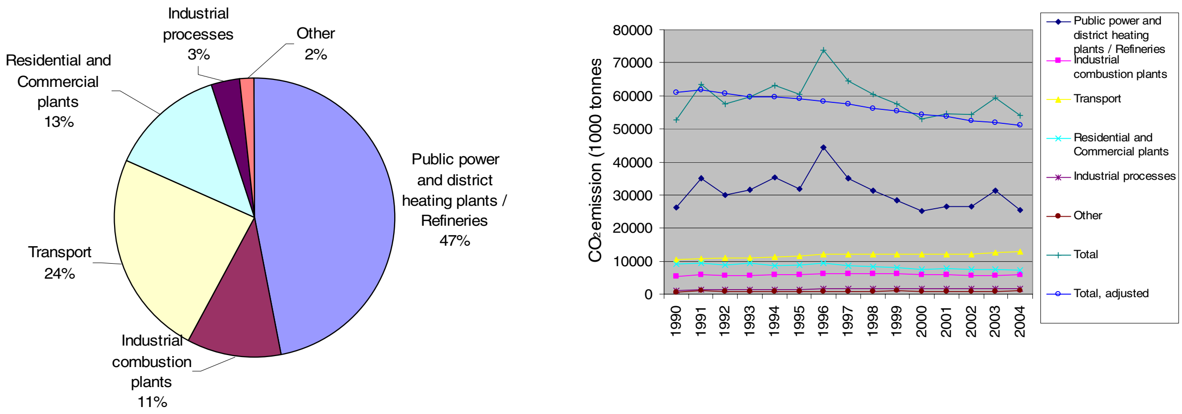


Figure 1.2 CO_2 emissions. Distribution according to the main sectors (2004) and time-series for 1990 to 2004.

1.3.2 Nitrous oxide

Agriculture is the most important N_2O emission source (Figure 1.3). N_2O is emitted as a result of microbial processes in the soil. Substantial emissions also come from drainage water and coastal waters, where nitrogen is converted to N_2O through bacterial processes. However, the nitrogen converted in these processes originates mainly from the agricultural use of manure and other fertilisers. The main reason for the drop in the emission of approximately 25% from 1990 to 2004 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. Approximately 10% of the emission of N_2O comes from combustion of fossil fuels, and transport accounts for around 6%. The N_2O emission from transport has increased during the nineties because of the increase in the use of catalyst cars. Emissions of N_2O from nitric acid production amount to approximately 7% of the total N_2O emission.

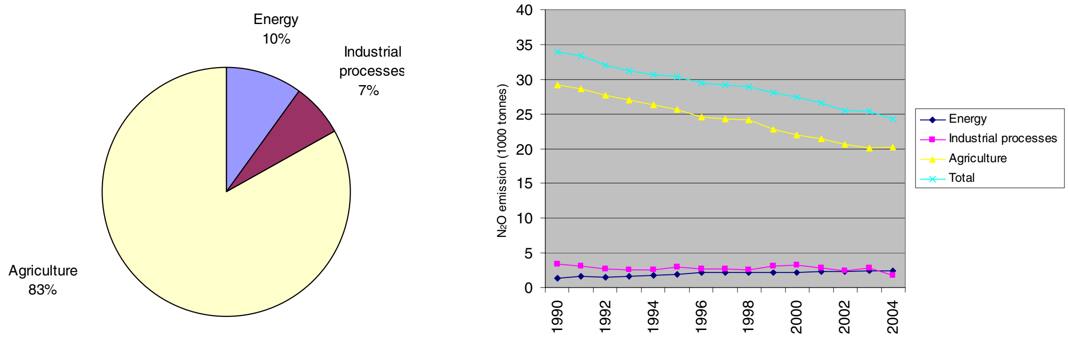


Figure 1.3 N_2O emissions. Distribution according to the main sectors (2004) and time-series for 1990 to 2004.

1.3.3 Methane

The largest sources of anthropogenic CH_4 emissions are agricultural activities, managed waste disposal on land, public power and district heating plants (Figure 1.4). The emission from agriculture derives from enteric fermentation and management of animal manure. The increasing CH_4 emission from public power and district heating plants is due to the increasing use of gas engines in the decentralised cogeneration plant sector. Approximately 3% of the natural gas in the gas engines is not combusted. From 1990, the emission of CH_4 from enteric fermentation has decreased due to the decrease in the number of cattle. However, the emission from manure management has increased due to a change away from traditional stable systems towards an increase in slurry-based stable systems. Altogether, the emission of CH_4 for the agricultural sector has decreased by approximately 7% from 1990 to 2004. The emission of CH_4 from waste disposal has decreased slightly due to increases in the incineration of waste.

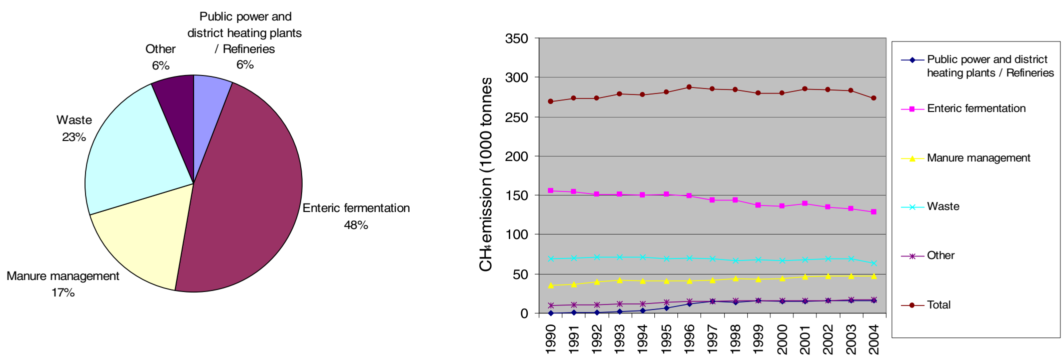


Figure 1.4 CH_4 emissions. Distribution according to the main sectors (2004) and time-series for 1990 to 2004.

1.3.4 HFCs, PFCs and SF_6

This part of the Danish inventory only comprises data 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 (Figure 1.5). This increase is simultaneous with the increase in the emission of HFCs. For the time-series 2000-2004, the increase has been much lower than for the years 1995 to 2000. SF_6 contributed considerably in earlier years, with

52% in 1993. Environmental awareness and regulation of this gas under Danish law has reduced its use in industry, with the result that the contribution in 2004 was approximately 4%. The use of HFCs, and especially HFC-134a as a major contributor to HFCs, has increased several fold. HFCs have, therefore, become dominant F-gases, comprising 48% in 1993, but 94% in 2004. HFC-134a is mainly used as a refrigerant. However, the use of HFC-134a as a refrigerant, as well as the use of other HFCs as refrigerants, is stable or falling. This is due to Danish legislation, which, in 2007, forbids new HFC-based refrigerant stationary systems. On the other hand, the use of air conditioning in mobile systems is on the increase.

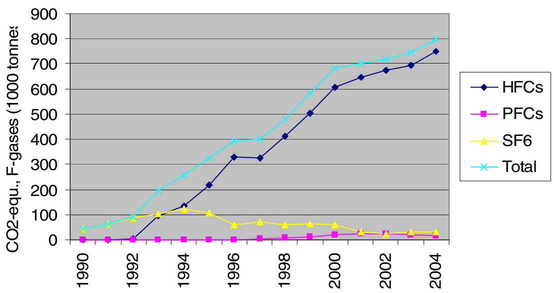


Figure 1.5 F-gas emissions. Time-series for 1990 to 2004.

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 assumption and simplifications. In the present project the emission factor method is used and the emission as a function of time for a given pollutant can be expressed as:

$$E = \sum_{s} A_s(t) \cdot \overline{EF}_s(t) \qquad (1.1)$$

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

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

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

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

Official Danish forecasts of activity rates are used in the models for those sectors for which the forecasts are available. For other sectors projected activity rates are estimated in co-operation with relevant research institutes and other organisations. The emission factors are based on recommendations from the IPCC Guidelines (IPCC, 1997), IPCC Good Practice Guidance and Uncertainty Management (2000) and the Joint EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2003) 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, 2003) 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, 2003). The projections are based on official activity rates forecast from the Danish Energy Authority 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), the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2003) 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 greenhouse gas 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 Authority's energy consumption projections to 2030 (Danish Energy Authority, 2006a) and energy projections for individual plants (Danish Energy Authority, 2006b) with the exception of two industrial plants where data are collected from Statistics Denmark and information obtained from the plants, themselves.

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 and two industrial plants. 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 Projected fuel consumption (TJ)

Fuel type	2005	2010	2015	2020	2025	2029	2030
Natural gas	215275	192224	224063	241663	212970	212432	212521
Steam coal	101790	166350	185922	129322	119265	103191	104132
Wood and simil.	45383	47023	49071	73896	74498	92632	93688
Municipal waste	42300	43642	43067	47205	49743	50424	50680
Gas oil	35993	29357	26611	27543	26444	26237	26285
Residual oil	24153	27181	28191	28193	26854	25000	25324
Agricultural waste	23870	27088	26877	24915	25390	25333	25100
Refinery gas	16555	16555	16555	16555	16555	16555	16555
Petroleum coke	8442	8382	8353	8336	8327	8325	8325
Biogas	3882	4626	4675	4672	4675	4667	4667
LPG	1682	1755	1710	1743	1757	1741	1737
Coke	813	840	891	973	1025	1051	1057
Kerosene	277	230	205	193	186	184	184
Total	520413	565252	616190	605207	567688	567774	570256

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 2008/2009 and decreases markedly in 2010. From 2010 to 2015 a small increase is seen, followed by a steady decrease until 2030. For wood the projected consumption increases throughout the period as a whole and in 2030 the consumption of wood is projected to be almost as high as the consumption of coal.

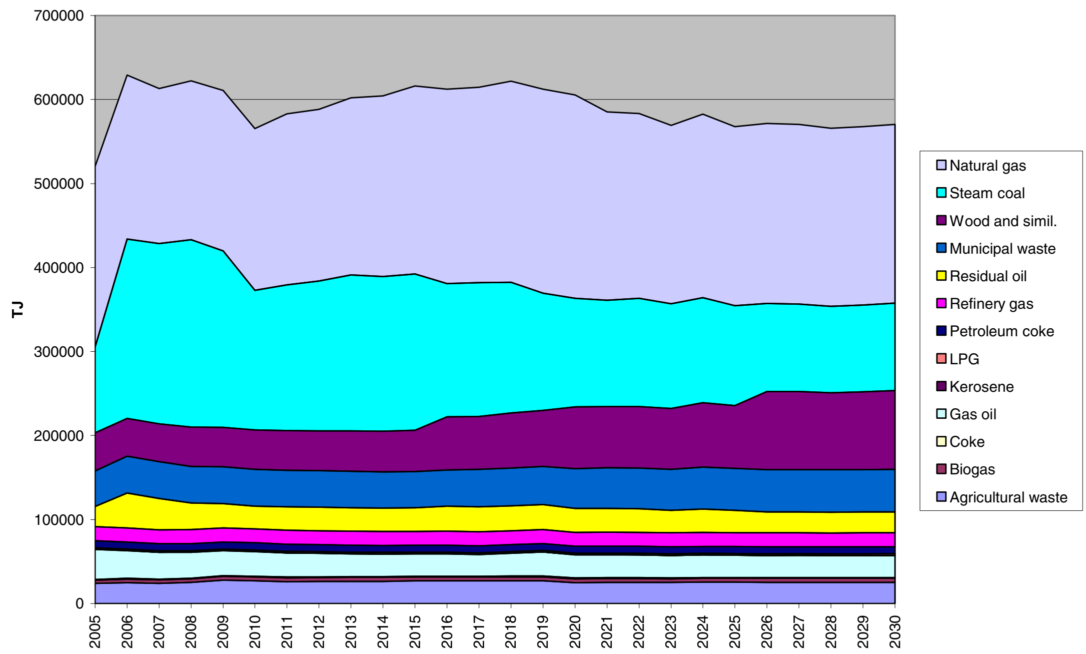

Figure 2.1 Projected energy consumption by fuel type.

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 more than 100 % from 2010 to 2020.

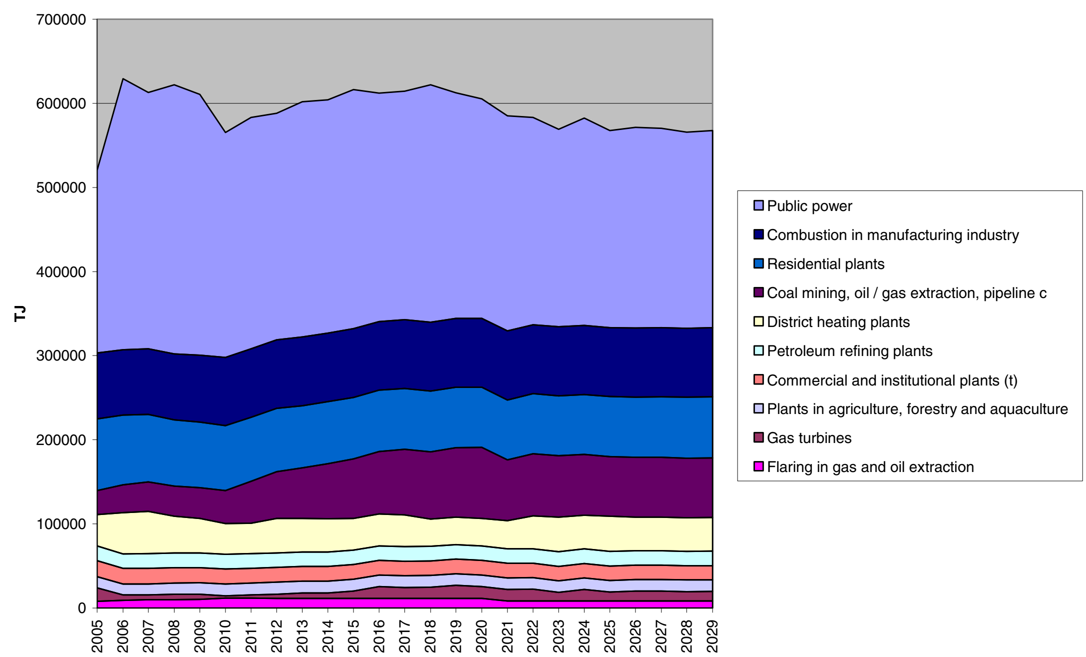

Figure 2.2 Energy use by sector

Power plants larger than 25 MWe use about 40 % of total fuel used and for these plants a rise in energy consumption is seen from 2005 to 2008, followed by a sharp fall in 2010 (Figure 2.3). The share of fuel use comprised by exported electricity constitutes 4-26 % of total fuel consumption over the period 2006 to 2030 (Figure 2.4).

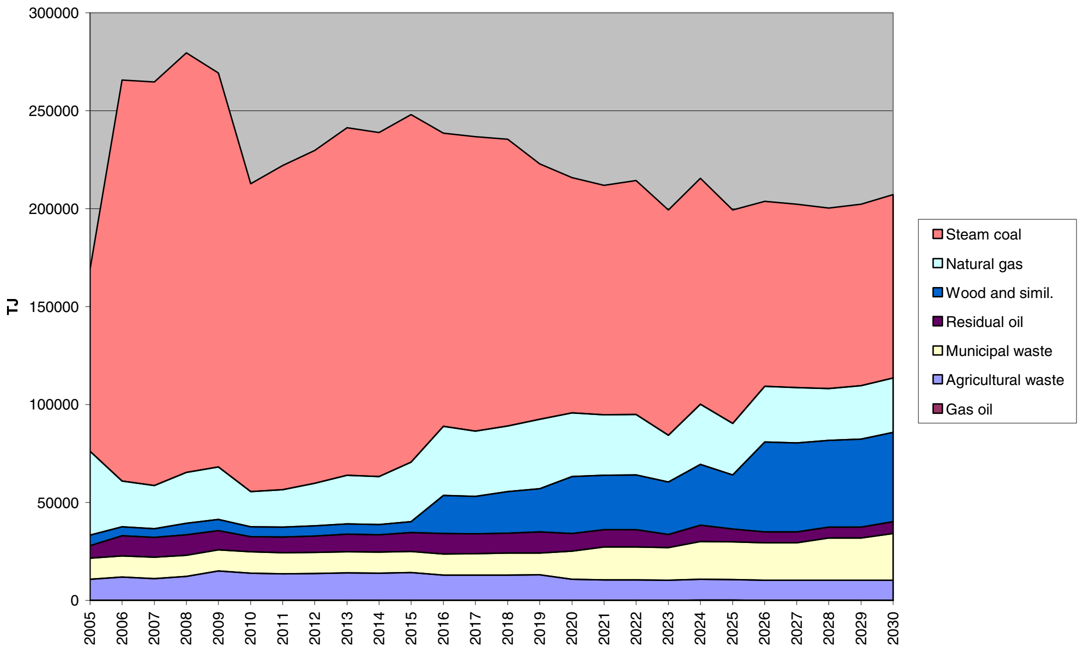

Figure 2.3 Energy consumption for plants > 25 MWe

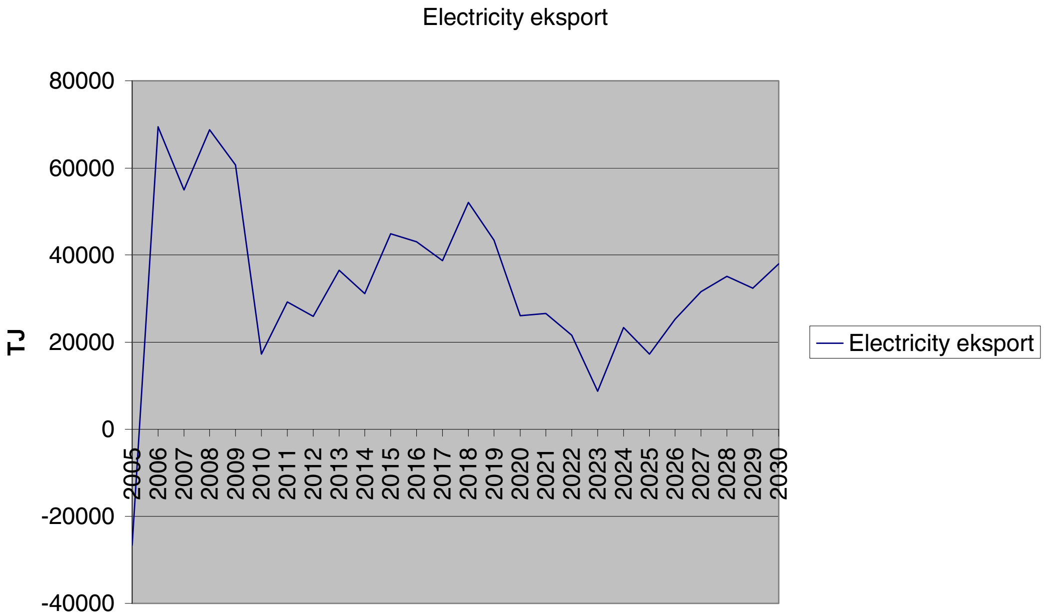

Figure 2.4 Fuel consumption associated with electricity export

2.4 Emission factors

2.4.1 Area sources

For area sources, emission factors for 2004 have been used (Nielsen, Nielsen and Illerup, 2006). The emission factor for CO_2 alone is 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. For these fuels, Implied Emission Factors (IEF) have therefore 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 2004-2030. 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 2004 are shown in Table 2.3. The IEFs are assumed to remain unchanged over the period 2004-2030 with one exception. For natural gas powered engines, new emission limit values came into force for existing plants in 2006.

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 2.3 CH_4 and N_2O for natural gas and biogas, calculation of Implied Emission Factors (IEF) based on emission factors from 2005 and fuel consumption in 2005

	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	839	2745	26392	15	2	485	428
CH_4	102	Natural gas	2040	-	474	15	2	485	104
CH_4	103	Natural gas	-	-	-	15	2	485	-
CH_4	105	Natural gas	361	27069	12	15	2	485	2
CH_4	201	Natural gas	8993	22	1033	15	2	485	63
CH_4	202	Natural gas	29922	-	1476	15	2	485	37
CH_4	203	Natural gas	2257	54	2864	15	2	485	275
CH_4	301	Natural gas	29966	6633	1570	15	2	485	32
CH_4	010103 - 5	Biogas	78	-	1435	4	4	323	307
CH_4	102	Biogas	23	-	36	4	4	323	198
CH_4	103	Biogas	-	-	-	4	4	323	-
CH_4	105	Biogas	-	-	61	4	4	323	323
CH_4	201	Biogas	612	-	517	4	4	323	150
CH_4	202	Biogas	-	-	-	4	4	323	-
CH_4	203	Biogas	268	-	411	4	4	323	197
CH_4	301	Biogas	158	-	17	4	4	323	35
N_2O	010103 - 5	Natural gas	839	2745	26392	1,00	2,20	1,30	1,37
N_2O	102	Natural gas	2040	-	474	1,00	2,20	1,30	1,06
N_2O	103	Natural gas	-	-	-	1,00	2,20	1,30	-
N_2O	105	Natural gas	361	27069	12	1,00	2,20	1,30	2,18
N_2O	201	Natural gas	8993	22	1033	1,00	2,20	1,30	1,03
N_2O	202	Natural gas	29922	-	1476	1,00	2,20	1,30	1,01
N_2O	203	Natural gas	2257	54	2864	1,00	2,20	1,30	1,18
N_2O	301		29966	6633	1570	1,00	2,20	1,30	1,22
N_2O	010103 - 5	Biogas	78	-	1435	2,00	2,00	0,50	0,58
N_2O	102	Biogas	23	-	36	2,00	2,00	0,50	1,09
N_2O	103	Biogas	-	-	-	2,00	2,00	0,50	-
N_2O	105	Biogas	-	-	61	2,00	2,00	0,50	0,50
N_2O	201	Biogas	612	-	517	2,00	2,00	0,50	1,31
N_2O	202	Biogas	-	-	-	2,00	2,00	0,50	-
N_2O	203	Biogas	268	-	411	2,00	2,00	0,50	1,09
N_2O	301	Biogas	158	-	17	2,00	2,00	0,50	1,85

2.4.2 Point sources

Plant-specific emission factors are not used for greenhouse gases. Therefore, emission factors for the individual fuels / SNAP categories are used. Point sources are, with a few exceptions, plants under SNAP 010101 / 010102 / 010103. A few plants come under other SNAP categories:

Gas turbines – here the emission factors for SNAP 010104 are used

Aalborg Portland – here the emission factors for SNAP 0301 are used

Junckers – here the emission factors for SNAP 0301 are used

Rexam Glas Holmegaard - here the emission factors for SNAP 0301 are used.

2.5 Emissions

Emissions for the individual greenhouse gases 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 in CO_2 equivalents (1 000 tonnes)

Sector	1990	2000	2005	'2010'	'2015'	2020	2025	2030
Public power	23 009	22 824	13831	20970	19333	15637	13513	12030
Gas turbines	0	0	922	282	577	876	639	692
District heating plants	1 852	286	1624	1779	1737	1455	2043	1884
Petroleum refining plants	908	999	1018	1018	1018	1018	1018	1018
Oil/gas extraction	546	1 467	1653	2499	4026	4856	4088	4088
Commercial and institutional plants	1 419	940	948	887	845	836	828	816
Residential plants	5 066	4 145	4037	3365	2962	2744	2618	2620
Plants in agriculture, forestry and aquaculture	620	779	764	798	819	810	802	806
Combustion in industrial plants	4 639		4762	4886	4975	5023	5052	5059
Flaring	265	5 146	459	626	654	654	475	475
Total	38 324	37 186	30017	37110	36947	33910	31077	29488

The projected emissions in 2008-2012 are approx. 1.200 ktonnes (CO_2-equiv.) lower than the emissions in 1990. From 1990 to 2030, the total emission falls by approx. 8,8oo ktonnes (CO_2-equiv.) or 23 % due to coal being partially replaced by renewable energy. The emission projections for the three greenhouse gases are shown in Figures 2.5-2.10 and in Tables 2.5-2.7, together with the historic emissions for 1990 and 2000 (Illerup et al. 2006).

2.5.1 CO_2 emissions

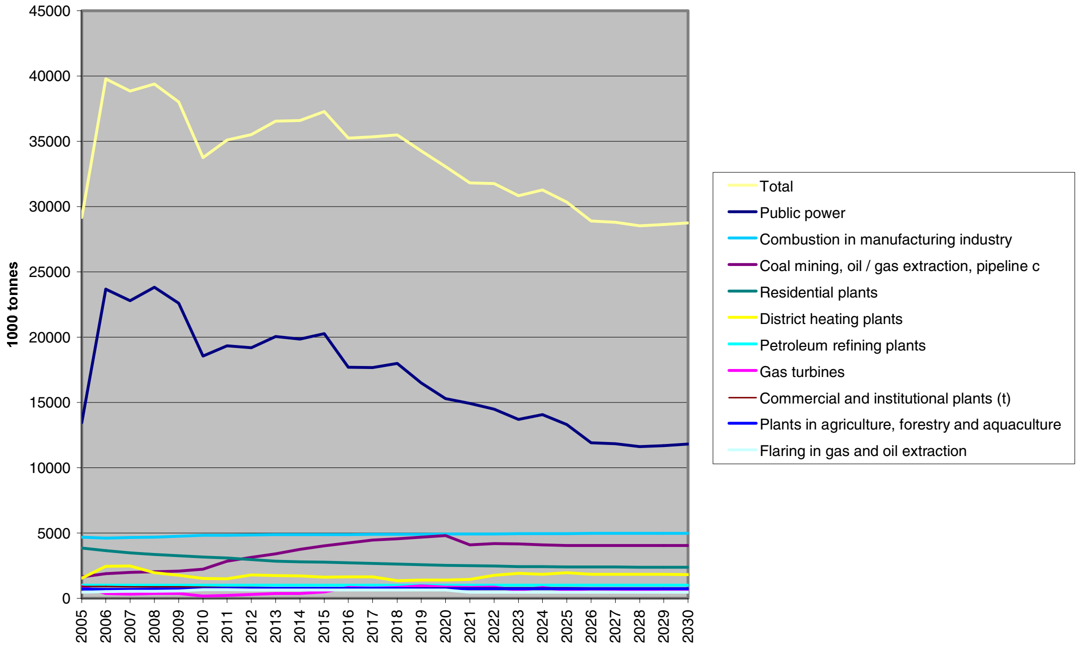

Figure 2.5 CO_2 emissions by sector

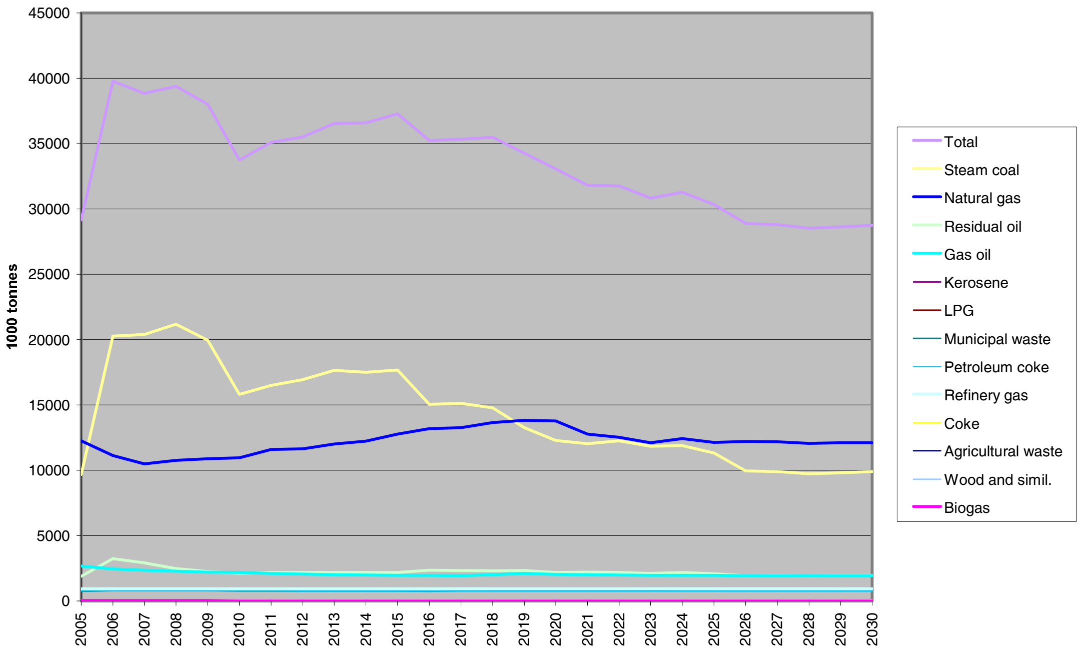

Figure 2.6 CO_2 emissions by fuel

Table 2.5 CO_2 emissions (ktonnes)

Sector	1990	2000	2005	'2010'	'2015'	2020	2025	2030
Public power	22 931	22 412	13456	20702	19109	15311	13311	11828
Gas turbines			910	278	570	867	631	684
District heating plants	1 805	265	1556	1709	1668	1403	1971	1816
Petroleum refining plants	897	988	1006	1006	1006	1006	1006	1006
Oil/gas extraction	540	1 449	1632	2468	3976	4796	4037	4037
Commercial and institutional plants	1403	913	915	856	815	806	798	787
Residential plants	4 946	4 003	3844	3169	2760	2535	2400	2392
Plants in agriculture, forestry and aquaculture	594	726	709	742	763	755	747	751
Combustion in industrial plants	4 582	5 067	4673	4796	4883	4930	4960	4967
Flaring	263	594	456	622	650	650	472	472
Total	37 961	36 419	29160	36348	36200	33060	30334	28741

CO_2 is the dominant greenhouse gas for stationary combustion and comprises, in 2010, approx. 98 % of total emissions in CO_2 equivalents. The most important source is the public power sector which contributes with about 58% in '2010' to the total emissions from stationary combustion plants. Other important sources are combustion plants in industry, residential and oil/gas extraction. The emission of CO_2 decreases by 21 % from 2015 to 2030 due to the partial shift in fuels from coal to wood and municipal waste.

2.5.2 CH_4 emissions

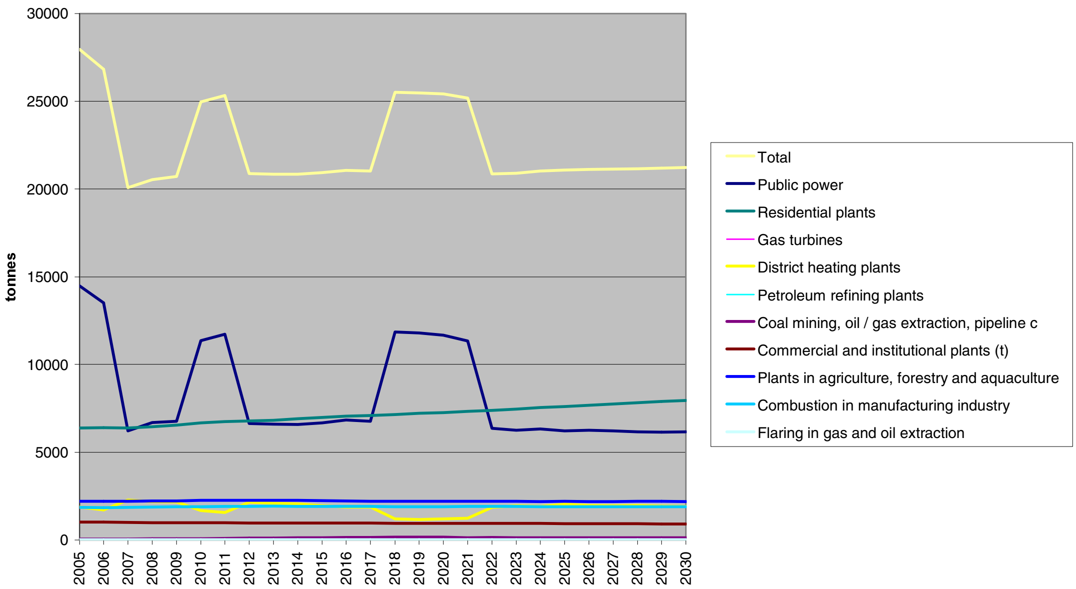

Figure 2 CH_4 emissions by sector

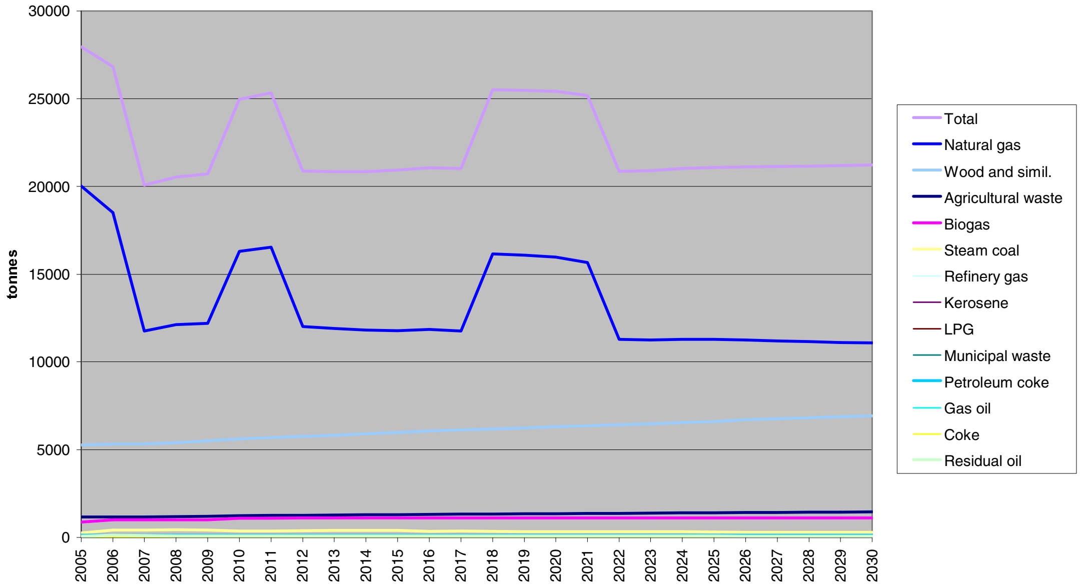

Figure 2.8 CH_4 emissions by fuel

Table 2.6 CH_4 emissions (tonnes)

Sector	1990	2000	2005	‘2010’	‘2015’	2020	2025	2030
Public power	595	14 402	14481	8633	6693	11666	6212	6155
Gas turbines	0	0	24	7	16	26	18	20
District heating plants	464	381	1877	1949	1973	1198	2039	1913
Petroleum refining plants	32	2	27	27	27	27	27	27
Oil/gas extraction	16	57	54	82	132	160	134	134
Commercial and institutional plants	189	912	1013	985	962	948	934	920
Residential plants	3 037	4 362	6390	6638	6972	7266	7606	7962
Plants in agriculture, forestry and aquaculture	793	2 130	2217	2244	2237	2203	2198	2195
Combustion in industrial plants	646	1 488	1858	1903	1918	1906	1904	1887
Flaring	84	111	8	11	11	11	8	8
Total	5 857	23 845	27948	22479	20942	25411	21081	21222

The two largest sources of CH_4 emissions are public power and residential plants, which also fits well with the fact that natural gas and wood are the fuels contributing most to the CH_4 emission. There is an apparent rise in emissions from 1990 to 2000 due to the increase in the use of gas engines during the 1990s.

2.5.3 N_2O emissions

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

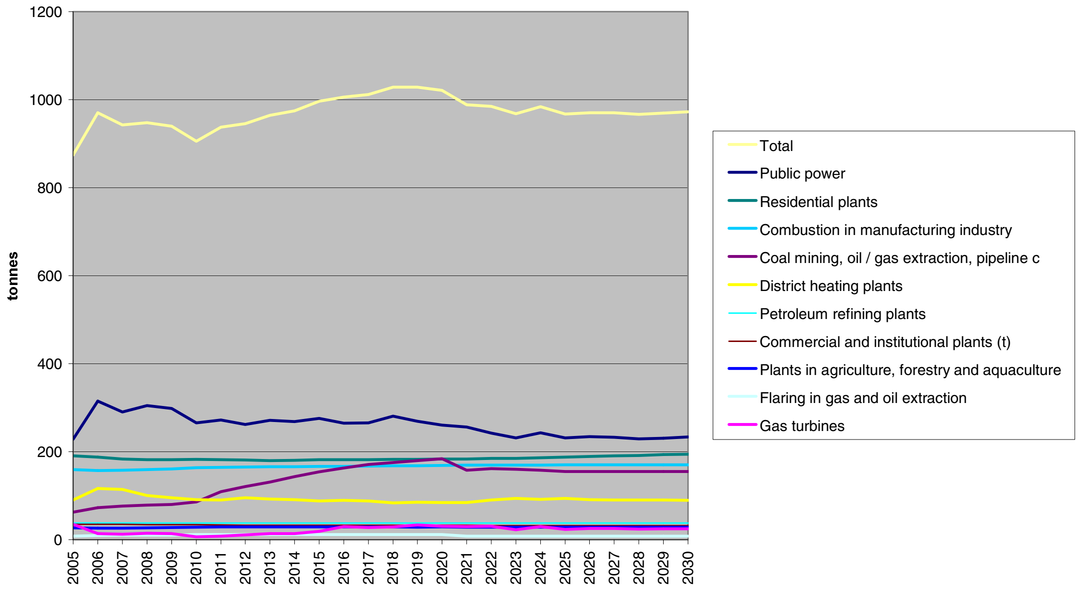

Figure 2.9 N_2O emissions by sector

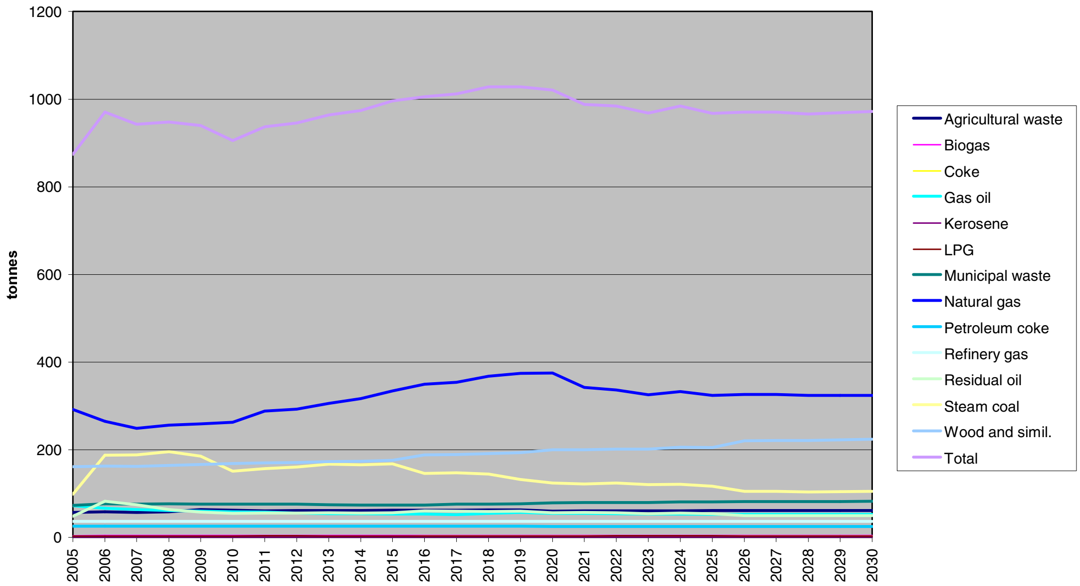

Figure 2.10 N_2O emissions by fuel

Table 2.7 N_2O emissions (tonnes)

Sector	1990	2000	2005	'2010'	'2015'	2020	2025	2030
Public power	212	354	229	280	269	260	231	233
Gas turbines	0	0	35	11	21	30	23	25
District heating plants	120	41	90	94	90	84	94	89
Petroleum refining plants	31	35	38	38	38	38	38	38
Oil/gas extraction	21	55	63	95	152	184	155	155
Commercial and institutional plants	39	25	35	34	33	32	32	32
Residential plants	182	161	190	182	181	183	187	194
Plants in agriculture, forestry and aquaculture	30	27	27	28	29	29	29	29
Combustion in industrial plants	141	152	159	163	166	169	170	170
Flaring	0	10	8	11	11	11	8	8
Total	775	860	1809	1925	2011	1988	1940	972

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 'Fremskrivning2005-2030 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 MWe and combustion plants smaller than 25 MWe. 'Area' and 'Point' in the model refer to small and large combustion plants, respectively. In Table 2.8 the names and the content of the tables are listed.

Table 2.8 Tables in the 'Fremskrivning2005-2030 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 'Fremskrivning2005-2030 model' (Figure 2.12). The outputs from the summation queries are Excel-pivot tables.

Table 2.10 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.

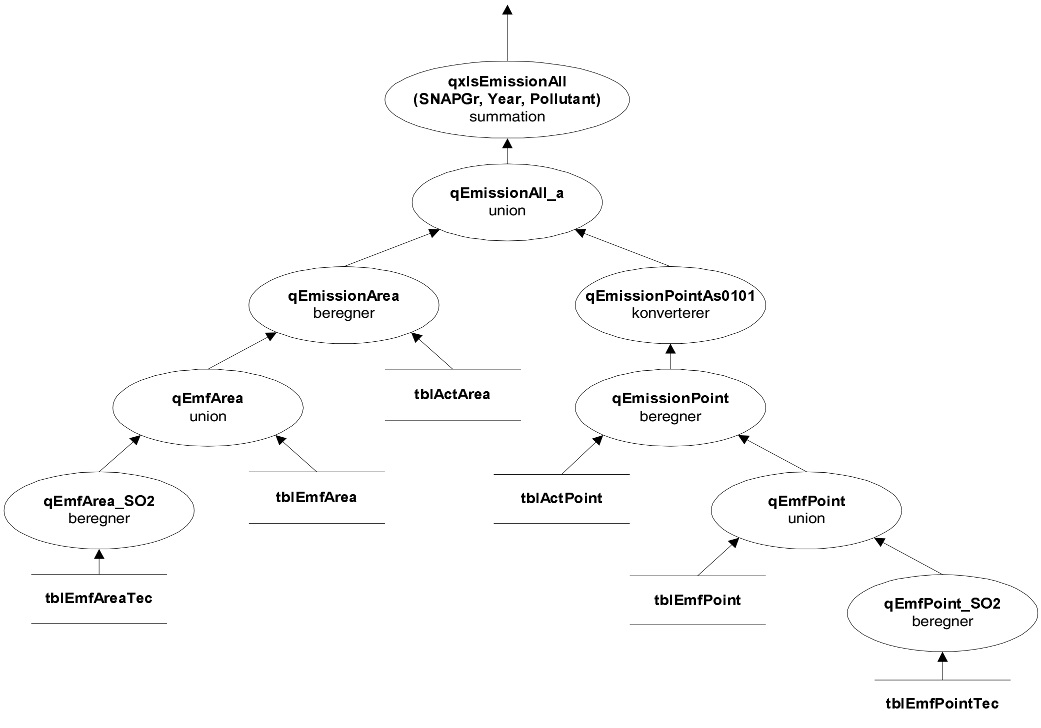

Figure 2.11 The overall construction of the database.

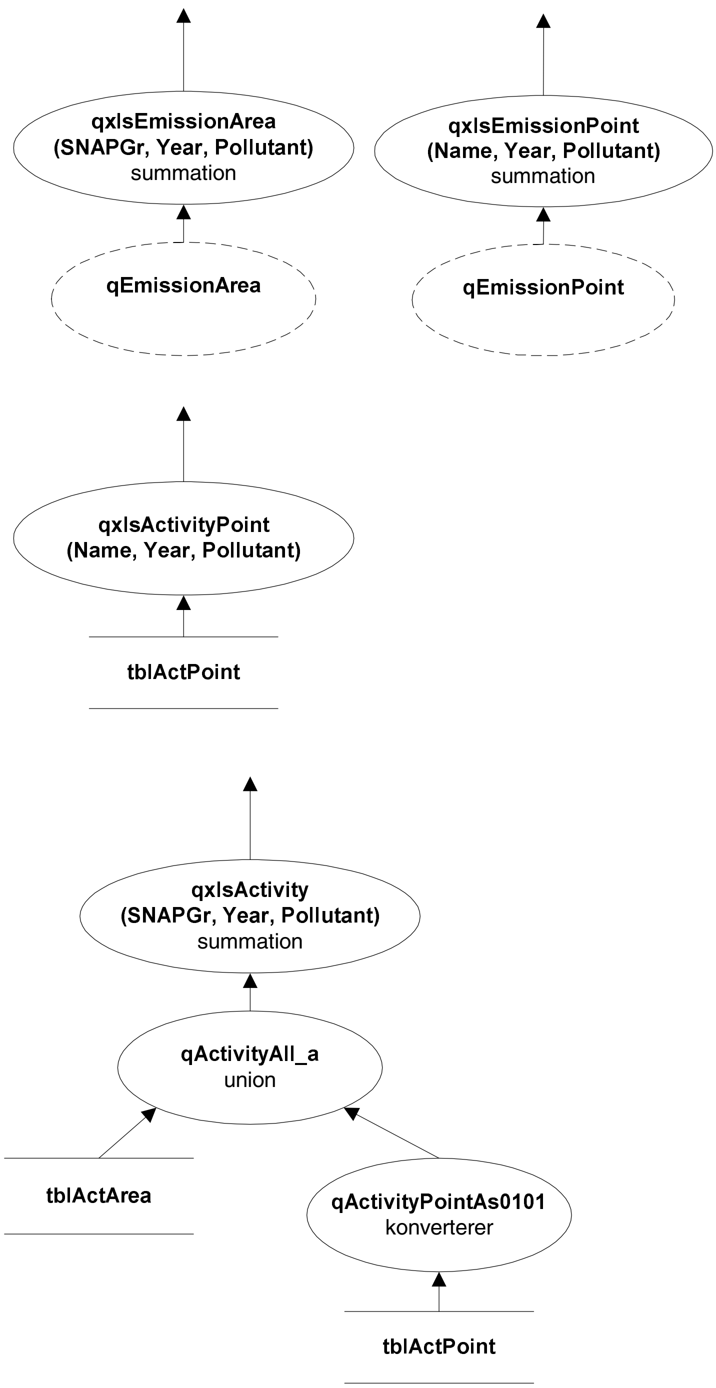

Figure 2.12 Summation queries.

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3 Oil and gas extraction (Fugitive emissions)

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, 2003), 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% methane and 25% NMVOC, then the methane 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:

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

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:

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

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:

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

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:

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

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 Authority's publications (Danish Energy Authority, 2005a and 2005b) or from DONG's environmental accounts ('grønne regnskaber') (DONG, 2005). The emissions from flaring are calculated in Chapter 2, 'Stationary Combustion'.

Table 3.1 Activity data for 2004

Activity	Symbol	Year 2005	Ref.
Number of platforms	N_p	48	Danish Energy Authority (2005a)
Gas produced (10^6Nm3)	P_{gas}	10 934	Danish Energy Authority (2005a)
Oil produced (10^3m3)	$P_{oil,vol}$	22 614	Danish Energy Authority (2005a)
Oil produced (10^3tonne)	P_{oil}	19 448	Danish Energy Authority (2005a)
Gas transported by pipeline (10^6Nm3)	T_{gas}	7 384	Danish Energy Authority (2005a)
Oil transported by pipeline (10^3m3)	T_{oil}	18 100	DONG (2005)
Oil transported by pipeline (10^3tonne)	T_{oil}	15 566	DONG (2005)
Oil loaded (10^3m3)	$L_{oil\ off\text{-}shore}$	4 774	Danish Energy Authority (2005a)
Oil loaded (10^3tonne)	$L_{oil\ off\text{-}shore}$	4 106	Danish Energy Authority (2005a)
Oil loaded (10^3m3)	$L_{oil\ on\text{-}shore}$	14 000	DONG (2005)
Oil loaded (10^3tonne)	$L_{oil\ on\text{-}shore}$	12 040	DONG (2005)
Volume gas consumed (10^6Nm3)	C_{gas}	3 248	Danish Energy Authority (2005b)

Mass weight crude oil = 0.86 tonne/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 Authority, 2006). A decline in the extraction of oil and gas from 2004 to 2030 is foreseen in the prognosis.

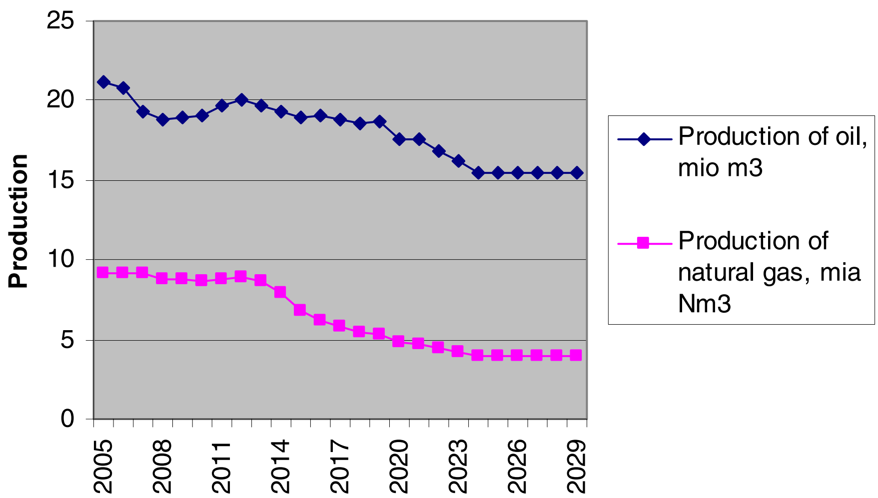

Figure 3.1 Prognosis for the production of oil and gas

3.3 Emission factors

In the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2003), 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 2004 (DONG, 2005) and the emission factor is calculated based on the amount of oil transported.

Table 3.2 Emission factors for 2005-2009.

	CH_4	Unit	Ref.
Ships offshore	0.00005	Fraction of loaded	EMEP/CORINAIR, 2003
Ships onshore	0.000002	Fraction of loaded	EMEP/CORINAIR, 2003
Pipeline, gas	11.51	kg/103m3	Karll, 2005
Oil tanks	113	kg/103m3	DONG, 2005
Network	11,37	kg/106m3	Karll, 2005

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, 2003
Ships onshore	0.00000108	Fraction of loaded	EMEP/CORINAIR, 2003 and Vejle Amt, 2005
Pipeline, gas	11.51	kg/103m3	Karll, 2005
Oil tanks	1,13	kg/103m3	DONG, 2005 and Vejle Amt 2005
Network	11,37	kg/106m3	Karll, 2005

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:	2004	2030
Fugitive	1 645	10 19
Gas treatment and storage:		
Fugitive + Flaring	60	31
Pipelines:		
Gas	74	31
Oil	n.a.	n.a.
Network	30	12
Oil tanks	2 193	14
Total minus ships	4 020	1 108
Ships:		
Offshore	158	140
Onshore	25	9
Total	4 203	1 257

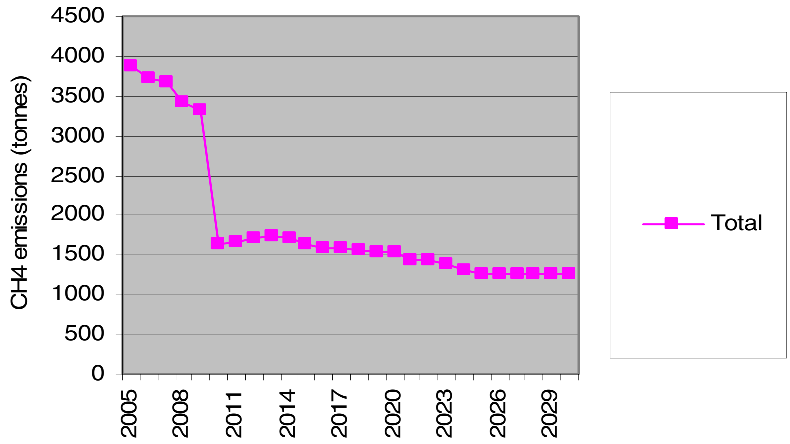

Figure 3.2 CH_4 emissions from oil and gas production

Table 3.5 CH_4 emissions (ktonnes)

IPCC name	IPCC code	1990	2000	2005	'2010'	2015'	2020	2025	2030
Fugitive emissions from oil	1B2a	1.54	3.48	3,70	2,18	1,51	1,43	1,18	1,18
Fugitive emissions from gas	1B2b	0.27	0.22	0.17	0.17	0.15	0.10	0.07	0.07
Total		1.81	3.70	3.86	2.35	1.65	1.54	1.26	1.26

Table 3.6 CH_4 emissions (ktonnes CO_2 equiv.)

IPCC name	IPCC code	1990	2000	2005	'2010'	'2015'	2020	2025	2030
Fugitive emissions from oil	1B2a	32	73	78	46	32	30	25	25
Fugitive emissions from gas	1B2b	6	5	4	4	3	2	2	2
Total		265	600	81	49	35	32	26	26

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 (Table 2.2.1) plus estimated activity rates for 2001 to 2010 based on data in table 'Projected production'.
Projected production	Projected production of oil and gas for 2001 to 2010.
EMF	Emission factors for NMVOC for all activities.
Emissions	Projected emissions for 2001 to 2010 based on data in tables 'Activity data' and 'Emission factors'.

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

References

Danish Energy Authority (2005a): Oil and Gas Production in Denmark 2004. www.ens.dk.

Danish Energy Authority (2005b): Energy Statistics (Energistatistik. Danmarks produktion og forbrug af energi (in Danish)). www.ens.dk

Danish Energy Authority (2006): Energy projections 2005-2030, October 2006.

DONG (2005): DONG's Environmental accounts (Miljø – og sikkerhedsrapport (in Danish)).

EMEP/CORINAIR (2003): EMEP/CORINAIR Emission Inventory Guidebook 3rd Edition September 2003 Update, Technical Report no 20, European Environmental Agency, Copenhagen. http://reports.eea.eu.int/EMEPCORINAIR4/en.

Flugsrud, K., Gjerald, E., Haakonson, G., Holtskog, S., Høie, H., Rypdal, K., Tornsjø, B. and Weidemann, F. (2000): The Norwegian Emission Inventory, Statistics Norway and Norwegian Pollution Control Authority. http://www.ssb.no/emner/01/90/rapp_200001/rapp_200001.pdf

Karll, B., (2005): Personal communication, e-mail 17 November 2003, Danish Technology Centre.

Vejle Amt, 2005: Pers. 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

The projection of emissions from industrial processes is based on the national emissions inventory (Illerup et al., 2006).

4.2 Projections

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

Aalborg Portland was contacted with regard to expectations for cement production in the future and the information was provided that budgeted production for 2007 was 2,786,800 tonne clinker (Aalborg Portland, 2005b). As production in 2004 totalled 2,861,471 tonne cement equivalents (tce) (Aalborg Portland, 2005a), the production forecast was already reached in 2004. The CO_2 emission is, therefore, regarded as constant at the 2004 level for the years 2005-2030.

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 2004 level for the years 2005-2030.

No forecasts are available for the production of glass and glass wool to 2030. The emission from these processes is, therefore, assumed to be constant at a level calculated as the average for the period 1990-2003.

'Other processes' includes CO_2 emissions from the use of lime to refine sugar, for the production of mineral wool and for flue gas cleaning. The emissions from sugar refining and the production of mineral wool are assumed to be constant at the 2004 level over the period 2005-2030. 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 Authority 2005, 2006). 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 Authority (2006))

	Coal TWh	SO_2	Extrapol.	Waste TWh	Extrapol.
2004[1]	47.2			10.3	
2005	26.1	18.4	0.55	10.4	1.02
2006	57.2	32.6	1.21	10.9	1.06
2007	57.5	29.7	1.22	10.9	1.06
2008	59.8	22.9	1.27	10.9	1.06
2009	56.1	22.5	1.19	10.9	1.06
2010	43.9	20.3	0.93	10.8	1.05
2011	46.0	19.0	0.97	10.8	1.05
2012	47.2	19.2	1.00	10.8	1.05
2013	49.3	19.4	1.04	10.7	1.04
2014	48.8	19.2	1.03	10.7	1.04
2015	49.3	20.0	1.04	10.7	1.04
2016	41.6	21.6	0.88	10.6	1.03
2017	41.7	21.0	0.88	11.0	1.08
2018	40.7	20.6	0.86	11.2	1.09
2019	36.2	21.4	0.77	11.3	1.10
2020	33.3	20.7	0.71	11.8	1.15
2021	32.6	20.1	0.69	12.1	1.18
2022	33.2	20.0	0.70	12.1	1.18
2023	32.0	19.4	0.68	12.2	1.18
2024	32.1	19.6	0.68	12.5	1.22
2025	30.4	18.6	0.64	12.5	1.22
2026	26.4	19.3	0.56	12.7	1.23
2027	26.2	19.3	0.55	12.7	1.23
2028	25.7	19.4	0.54	12.7	1.24
2029	25.9	19.4	0.55	12.7	1.24
2030	26.1	19.6	0.55	12.8	1.24

Energy Statistics 2004 (Danish Energy Authority, 2005).

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 was 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 take over by Duferco; the future for the electro steelwork (DanScan Steel) is still uncertain. Treatment of steel scrap and, thereby, the process-related emission of CO_2 is assumed to be at the same level as when production ceased.

Table 4.3 Projection of process emissions

	2A	2B	2C	2B	2B	Total
	kt CO_2	kt CO_2	kt CO_2	kt N_2O	kt CO_2-equiv.	kt CO_2-equiv.
1990	1 069	0.80	28.4	3.36	1 043	2 141
1991	1 247	0.80	28.4	3.08	955	2 232
1992	1 367	0.80	28.4	2.72	844	2 239
1993	1 384	0.80	31.0	2.56	795	2 211
1994	1 408	0.80	33.5	2.60	807	2 248
1995	1 406	0.80	38.6	2.92	904	2 349
1996	1 515	1.45	35.2	2.69	834	2 385
1997	1 682	0.87	35.0	2.74	848	2 566
1998	1 679	0.56	42.2	2.60	807	2 528
1999	1 606	0.58	43.0	3.07	950	2 600
2000	1 635	0.65	40.7	3.24	1 004	2 680
2001	1 658	0.83	46.7	2.86	885	2 591
2002	1 694	0.55	0.0	2.50	774	2 469
2003	1 569	1.05	0.0	2.89	896	2 466
2004	1 728	3.01	0.0	1.45	448	2 179
2005	1 703	3.00	45.0	0	0	1 751
2006	1 740	3.00	45.0	0	0	1 788
2007	1 740	3.00	45.0	0	0	2 141
2008	1 743	3.00	45.0	0	0	1 791
2009	1 738	3.00	45.0	0	0	1 786
2010	1 724	3.00	45.0	0	0	1 772
2011	1 726	3.00	45.0	0	0	1 774
2012	1 728	3.00	45.0	0	0	1 776
2013	1 730	3.00	45.0	0	0	1 778
2014	1 730	3.00	45.0	0	0	1 778
2015	1 730	3.00	45.0	0	0	1 778
2016	1 721	3.00	45.0	0	0	1 769
2017	1 722	3.00	45.0	0	0	1 770
2018	1 720	3.00	45.0	0	0	1 768
2019	1 715	3.00	45.0	0	0	1 763
2020	1 712	3.00	45.0	0	0	1 760
2021	1 711	3.00	45.0	0	0	1 759
2022	1 712	3.00	45.0	0	0	1 760
2023	1 710	3.00	45.0	0	0	1 758
2024	1 710	3.00	45.0	0	0	1 758
2025	1 709	3.00	45.0	0	0	1 757
2026	1 704	3.00	45.0	0	0	1 752
2027	1 704	3.00	45.0	0	0	1 752
2028	1 703	3.00	45.0	0	0	1 751
2029	1 703	3.00	45.0	0	0	1 751
2030	1 704	3.00	45.0	0	0	1 752

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

Table 4.4 Summary of results of projection of process emissions

		1990	2000	2005	'2010' 2008-2012	'2015' 2013-2017	2020	2025
2A Mineral products	kt CO_2-eq.	1 069	1 635	1 703	1 732	1 727	1 712	1 709
2B Chemical industry	kt CO_2-eq.	1 044	1 004	3.00	3.00	3.00	3.00	3.00
2C Metal production	kt CO_2-eq.	28.4	40.7	45.0	45.0	45.0	45.0	45.0

References

Danish Energy Authority (2006): Energy projections 2005-2030, October 2006.

Danish Energy Authority (2005): Energistatistik. Danmarks produktion og forbrug af energi 2004 (in Danish). www.ens.dk

Illerup, J.B., Lyck, E., Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Nielsen, M., Sørensen, P.B., Fauser, P., Thomsen, M. & Winther, M. (2006). Denmark's National Inventory Report 2006. Submitted under the United Nations Framework Convention on Climate Change, 1990-2004. NERI Technical Report No. 589.

Aalborg Portland (2005a). Environmental report 2004.

Aalborg Portland (2005b). Henrik Møller Thomsen, personal communication, 9 March 2005.

5 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 5.1 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.

5.1 Methodology and references for road transport

For road transport the emission calculations are made with a model developed by NERI, using the detailed methodology from the European COPERT III model. The latter model approach is explained by Ntziachristos et al. (2000) and EMEP/CORINAIR (2003). In COPERT III fuel use 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.

5.1.1 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 use 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 5.2 Model vehicle classes and sub-classes, trip speeds and mileage split

			Trip speed [km/h]			Mileage split [%]		
Vehicle classes	Fuel type	Engine size/weight	Urban	Rural	Highway	Urban	Rural	Highway
PC	Gasoline	< 1.4 l.	40	70	100	35	46	19
PC	Gasoline	1.4 – 2 l.	40	70	100	35	46	19
PC	Gasoline	> 2 l.	40	70	100	35	46	19
PC	Diesel	< 2 l.	40	70	100	35	46	19
PC	Diesel	> 2 l.	40	70	100	35	46	19
PC	LPG		40	70	100	35	46	19
PC	2-stroke		40	70	100	35	46	19
LDV	Gasoline		40	65	80	35	50	15
LDV	Diesel		40	65	80	35	50	15
Trucks	Gasoline		35	60	80	32	47	21
Trucks	Diesel	3.5 – 7.5 tonnes	35	60	80	32	47	21
Trucks	Diesel	7.5 – 16 tonnes	35	60	80	32	47	21
Trucks	Diesel	16 – 32 tonnes	35	60	80	19	45	36
Trucks	Diesel	> 32 tonnes	35	60	80	19	45	36
Urban buses	Diesel		30	50	70	51	41	8
Coaches	Diesel		35	60	80	32	47	21
Mopeds	Gasoline		30	30	-	81	19	0
Motorcycles	Gasoline	2 stroke	40	70	100	47	39	14
Motorcycles	Gasoline	< 250 cc.	40	70	100	47	39	14
Motorcycles	Gasoline	250 – 750 cc.	40	70	100	47	39	14
Motorcycles	Gasoline	> 750 cc.	40	70	100	47	39	14

Information on the historical vehicle stock and annual mileage is obtained from the Danish Road Directorate (Ekman, 2005a). This covers data for the number of vehicles and annual mileage per first registration year for all vehicle sub-classes, and mileage split between urban, rural and highway driving and the respective average speeds. Additional data for the moped fleet and motorcycle fleet disaggregation information is given by The National Motorcycle Association (Markamp, 2005).

To support the emission projections carried out by Illerup et al. (2002), a vehicle fleet and mileage prognosis was produced by the Danish Road Directorate. The general approach was to assume new sales of vehicles and the mean lifespan of vehicles in the years contained in the forecast period, by undertaking historical data analyses and using economic parameters. Subsequently, the prognosis data has been modified for later Danish emission forecast projects. The latest data adjustments were made by Ekman (2005b) as a part of the present emission forecast.

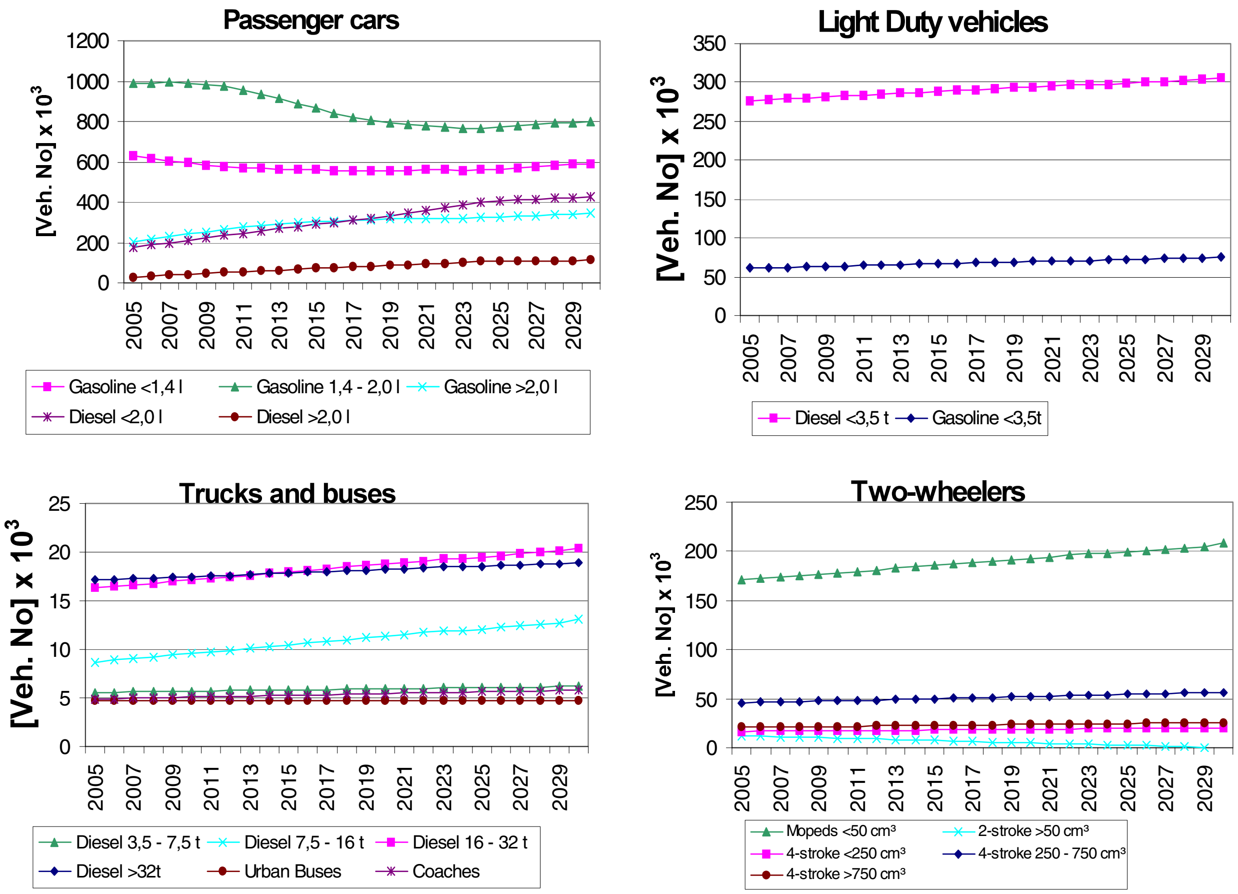

Figure 5.1 Number of vehicles in sub-classes in 1985-2030

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:

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

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.

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

Vehicle numbers and weighted annual mileages per layer are shown in Annex 5.1 for 2005-2030. The trends in vehicle numbers per layer are also shown in Figure 5.2. The latter figure shows how vehicles complying with the gradually stricter EU emission levels (EURO I, II, III etc.) are introduced into the Danish motor fleet in the forecast period.

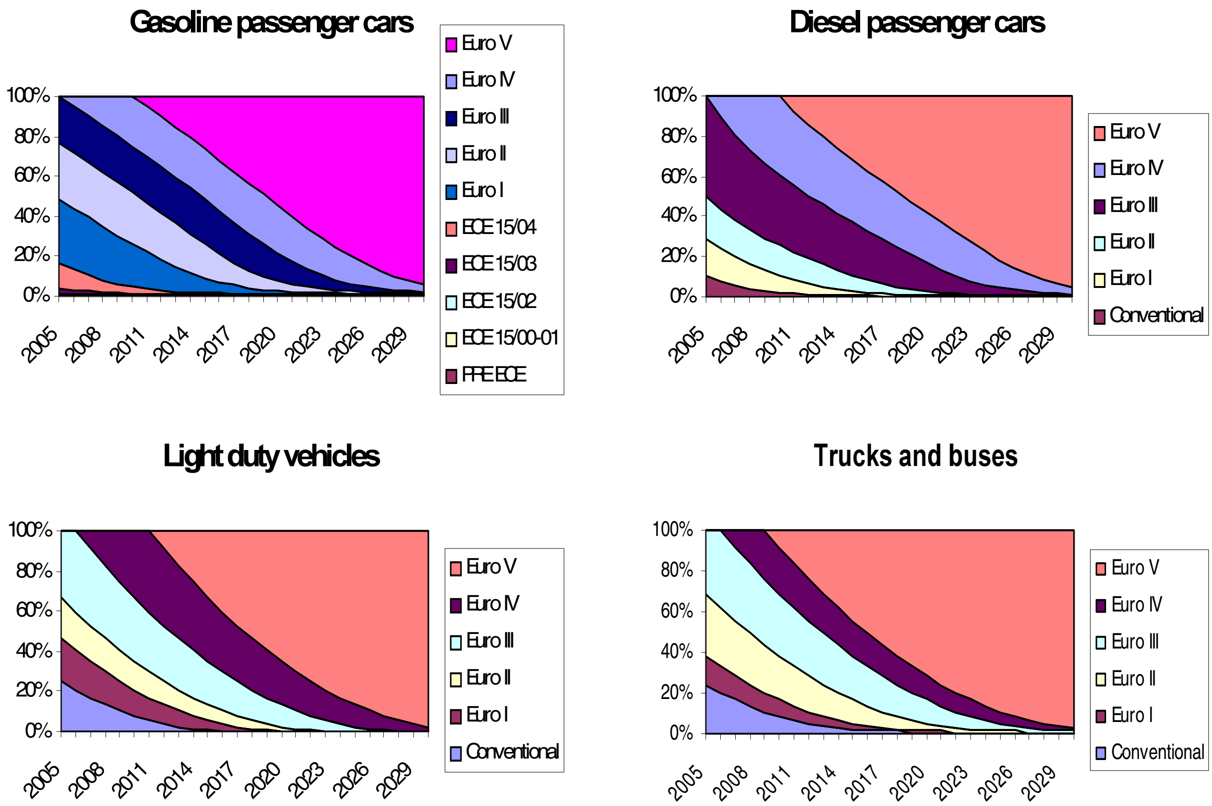

Figure 5.2 Layer distribution of vehicle numbers per vehicle type in 2005-2030

5.1.2 Emission legislation

No specific emission legislation exists for CO_2; an EU strategy has, however, been formulated to improve the fuel efficiency for new vehicles sold in the EU. The goal is to bring down the average CO_2 emissions to 120 g/km in 2010. The means by which the CO_2 target is to be met are:

- An agreement with the car manufacturers in Europe, Japan and Korea that new private cars sold in the EU in 2008/2009 emit, on average, CO_2 emissions of 140 or less g/km.
- Energy labelling information from EU member states to car buyers.
- The use of fiscal instruments to promote fuel efficient cars.

The test cycle used in the EU for measuring fuel is the NEDC (New European Driving Cycle) used also for emission testing. The NEDC cycle consists of two parts, the first part being a 4-times repetition (driving length: 4 km) of the ECE test cycle, the so-called urban driving cycle (average speed: 19 km/h). The second part of the test is the EUDC (Extra Urban Driving Cycle) test driving segment, simulating the fuel use under rural and highway driving conditions. The driving length in the EUDC is 7 km at an average speed of 63 km/h. More information regarding the fuel measurement procedure can be found in the EU Directive 80/1268/EØF.

For NO_X, VOC, CO and TSP, the emissions from road transport vehicles have to comply with the various EU directives listed in Table 5.3. Even though the directives do not regulate the emissions of CH_4 and N_2O, the VOC emission limits influence the emissions of CH_4, the latter being a part of total VOC. The specific emission limits can be seen in Winther (2006).

Table 5.3 Overview of the existing EU emission directives for road transport vehicles

Vehicle category	Emission layer	EU Directive	First reg. year	
			start	end
Private cars (gasoline)	PRE ECE		0	1969
	ECE 15/00-01	70/220 - 74/290	1970	1978
	ECE 15/02	77/102	1979	1980
	ECE 15/03	78/665	1981	1985
	ECE 15/04	83/351	1986	1990
	Euro I	91/441	1991	1996
	Euro II	94/12	1997	2000
	Euro III	98/69	2001	2005
	Euro IV	98/69	2006	9999
Private cars (diesel and LPG)		Conventional	0	1990
	Euro I	91/441	1991	1996
	Euro II	94/12	1997	2000
	Euro III	98/69	2001	2005
	Euro IV	98/69	2006	2010
	Euro V		2011	9999
Light duty veh. (gasoline and die-		Conventional	0	1994
	Euro I	93/59	1995	1998
	Euro II	96/69	1999	2001
	Euro III	98/69	2002	2006
	Euro IV	98/69	2007	9999
	Euro V		2012	9999
Heavy duty vehicles		Conventional	0	1993
	Euro I	91/542	1994	1996
	Euro II	91/542	1997	2001
	Euro III	1999/96	2002	2006
	Euro IV	1999/96	2007	2009
	Euro V	1999/96	2010	9999
Mopeds		Conventional	0	1999
	Euro I	97/24	2000	2002
	Euro II	97/24	2003	9999
Motor cycles		Conventional	0	1999
	Euro I	97/24	2000	2003
	Euro II	2002/51	2004	2006
	Euro III	2002/51	2007	9999

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 and Hansen, 2004). The emission directives distinguish between three vehicle classes: passenger cars and light duty vehicles (<1305 kg), light duty vehicles (1305-1760 kg) and light duty vehicles (>1760 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 must be chosen which derive from numerous emissions measurements, using a broad range of real world driving patterns and sufficient numbers of test vehicles. It is similarly important to have separate fuel use 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/kWh, and the measurements are carried out for engines in a test bench, using the EU ESC (European Stationary Cycle) and ETC (European Transient Cycle) test cycles, depending on the Euro norm and the exhaust gas after treatment system installed. A description of the test cycles are given by Nørgaard and Hansen (2004). Measurement results in g/kWh from emission approval tests cannot be directly used for inventory work. Instead, emission factors used for national estimates must be transformed into g/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.

5.1.3 Fuel use and emission factors

Trip speed dependent basis factors for fuel use and emissions are taken from the COPERT model using trip speeds as shown in Table 5.2. The factors can be seen in Winther (2006). The scientific basis for COPERT III is fuel use and emission information from various European measurement programmes, transformed into trip speed dependent fuel use and emission factors for all vehicle categories and layers. For passenger cars and light duty vehicles, real measurement results are behind the emission factors for Euro I vehicles and before, whereas the experimental basis for heavy duty vehicles are computer simulated emission factors for pre Euro I engines. In both cases, the emission factors for later engine technologies are produced by using reduction factors (see Winther, 2006). 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.

5.1.4 Fuel use and emission calculations

The fuel use and emissions are calculated for operationally hot engines and for engines during cold start, and 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 use and emission factors (see Winther, 2006), 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 (2006).

Fuel use and emission results per layer and vehicle type, respectively, are shown in Annex 5.1 from 2005-2030. 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.

5.2 Other mobile sources

The other mobile sources are divided into several sub-sectors; sea transport, fishery, air traffic, railways, military and the working machinery and materiel in the industry, forestry, agriculture and household and gardening sectors. The emission calculations are made using the detailed method as described in the EMEP/CORINAIR Emission Inventory Guidebook (EMEP/CORINAIR, 2003) for air traffic and off road working machinery and equipment, while for the remaining sectors the simple method is used.

5.2.1 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 2001-2004, 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 use and aviation gasoline are obtained from the Danish energy statistics (DEA, 2005).

No forecast of air traffic movements is available as input to the emission projection calculations. Instead, a forecast of total fuel used by Danish domestic flights from 2005-2030 is used as activity data in the projection period.

Prior to emission calculations for historical years, the aircraft types are grouped into a smaller number of representative aircraft for which fuel use 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 MTOM (Maximum Take-Off Mass) 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).

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 5.4 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	Silv. 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 new 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.

Other sectors

The activity data for military, railways, sea transport and fishery consists of fuel use information from DEA (2005). For sea transport the basis is fuel sold in Danish ports. Depending on the destination of the vessels in question, the traffic is defined as either national or international, as prescribed by the IPCC guidelines. A new Danish research project has carried out detailed calculations for Danish Ferries, and more information of ferry activity data can be obtained from Winther (2007).

For all other mobile sectors, fuel use figures are given in Annex 5.2 for the years 2005-2030 in both CollectER and CRF formats.

5.2.2 Emission legislation

For the engines used by other mobile sources, no legislation limits exist for specific fuel use 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/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 use) 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 of the machinery type in question, and the test cycles are described in more detail in the directives.

Table 5.5 Overview of EU emission directives relevant for diesel fuelled non road machinery

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

Table 5.6 Overview of the EU emission directive 2002/88 for gasoline fuelled non road machinery

	Category	Engine size [ccm]	CO [g/kWh]	HC [g/kWh]	NO_X [g/kWh]	HC+NO_X [g/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 5.7. 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 5.7 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 5.8 Overview of the EU emission directive 2004/26 for railway locomotives and motor cars

	Engine size [kW]		CO [g/kWh]	HC [g/kWh]	NO_X [g/kWh]	HC+NO_X [g/kWh]	PM [g/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 ICAO (International Civil Aviation Organization). The legislation is relevant for aircraft engines with rated engine thrust larger than 26.7 kN. A further description of the emission legislation and emission limits is given in ICAO Annex 16 (1993).

5.2.3 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/CORINAIR guidebook (CORINAIR, 2003). 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 (Næraa, 2005) 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 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/CORINAIR guidebook (CORINAIR, 2003). 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 2005-2030.

5.2.4 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 use and emissions are calculated as the product of the number of engines, annual working hours, average rated engine size, load factor, and fuel use/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 (2006),

Other sectors

For Danish ferries the fuel use and emissions are calculated as the product of the number of round trips, sailing time per round trip, engine size, load factor, and fuel use/emission factors. Please refer to Winther (2007) for more details regarding this calculation procedure. For other national sea traffic, fishing vessels, military and railways, the emissions are estimated with the simple method using fuel-related emission factors and fuel use from the DEA.

5.3 Fuel use and emission results

An overview of the fuel use and emission results is given in Table 5.8 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 5.9 Summary table of fuel use and emissions for mobile sources in Denmark

		1990	2000	2005	'2010'	'2015'	2020	2025	2030
Energy	Industry - Other (1A2f)	12	12	12	12	12	12	12	12
	Civil Aviation (1A3a)	3	2	2	2	2	2	2	2
	Road (1A3b)	126	152	168	174	179	186	191	195
	Railways (1A3c)	4	3	3	3	3	3	3	3
	Navigation (1A3d)	7	6	6	6	6	6	6	6
	Residential (1A4b)	2	2	4	4	4	4	4	4
	Ag./for./fish. (1A4c)	28	23	22	21	21	21	21	21
	Military (1A5)	2	2	2	2	2	2	2	2
	Navigation int. (1A3d)	40	56	41	41	41	41	41	41
	Civil Aviation int. (1A3a)	24	33	31	32	34	37	40	42
CO_2	Industry - Other (1A2f)	842	879	912	905	901	883	875	872
	Civil Aviation (1A3a)	243	154	128	133	141	152	162	172
	Road (1A3b)	9241	11159	12338	12764	13150	13685	14023	14327
	Railways (1A3c)	297	228	202	202	202	202	202	202
	Navigation (1A3d)	555	463	469	428	418	418	418	418
	Residential (1A4b)	138	169	297	290	287	287	287	287
	Ag./for./fish. (1A4c)	2079	1684	1619	1586	1543	1528	1533	1524
	Military (1A5)	119	111	122	122	122	122	122	122
	Navigation int. (1A3d)	3087	4279	3138	3138	3138	3138	3138	3138
	Civil Aviation int. (1A3a)	1736	2350	2254	2335	2457	2672	2849	3038
CH_4	Industry - Other (1A2f)	60	50	44	37	33	30	29	29
	Civil Aviation (1A3a)	7	5	4	4	5	5	5	6
	Road (1A3b)	2456	3244	2952	2192	1490	1104	977	939
	Railways (1A3c)	12	10	8	3	2	0	0	0
	Navigation (1A3d)	34	33	33	32	31	31	31	31
	Residential (1A4b)	182	177	291	279	261	258	258	258
	Ag./for./fish. (1A4c)	144	90	76	65	60	57	56	55
	Military (1A5)	5	5	5	5	4	4	4	4
	Navigation int. (1A3d)	70	97	74	76	79	81	82	83
	Civil Aviation int. (1A3a)	31	42	43	44	47	51	54	58
N_2O	Industry - Other (1A2f)	34	37	39	38	38	38	38	38
	Civil Aviation (1A3a)	10	8	8	9	9	10	10	11
	Road (1A3b)	402	1172	1471	1643	1739	1843	1927	1984
	Railways (1A3c)	8	6	6	6	6	6	6	6
	Navigation (1A3d)	32	26	26	24	24	24	24	24
	Residential (1A4b)	2	3	5	5	5	5	5	5
	Ag./for./fish. (1A4c)	98	83	80	79	78	78	78	77
	Military (1A5)	4	4	7	8	8	9	9	9
	Navigation int. (1A3d)	194	270	198	198	198	198	198	198
	Civil Aviation int. (1A3a)	59	82	78	81	85	93	99	105
GHG-eq.	Industry - Other (1A2f)	853	892	925	917	914	895	887	884
	Civil Aviation (1A3a)	246	157	130	136	144	155	165	176
	Road (1A3b)	9418	11591	12856	13320	13721	14279	14641	14961
	Railways (1A3c)	300	230	204	204	204	204	204	204
	Navigation (1A3d)	566	472	477	437	426	426	426	426
	Residential (1A4b)	142	174	305	298	294	294	294	294
	Ag./for./fish. (1A4c)	2112	1711	1645	1612	1569	1553	1558	1549
	Military (1A5)	120	112	124	124	125	125	125	125
	Navigation int. (1A3d)	3149	4365	3201	3201	3201	3201	3201	3201
	Civil Aviation int. (1A3a)	1755	2376	2279	2361	2485	2701	2881	3072

5.3.1 Road transport

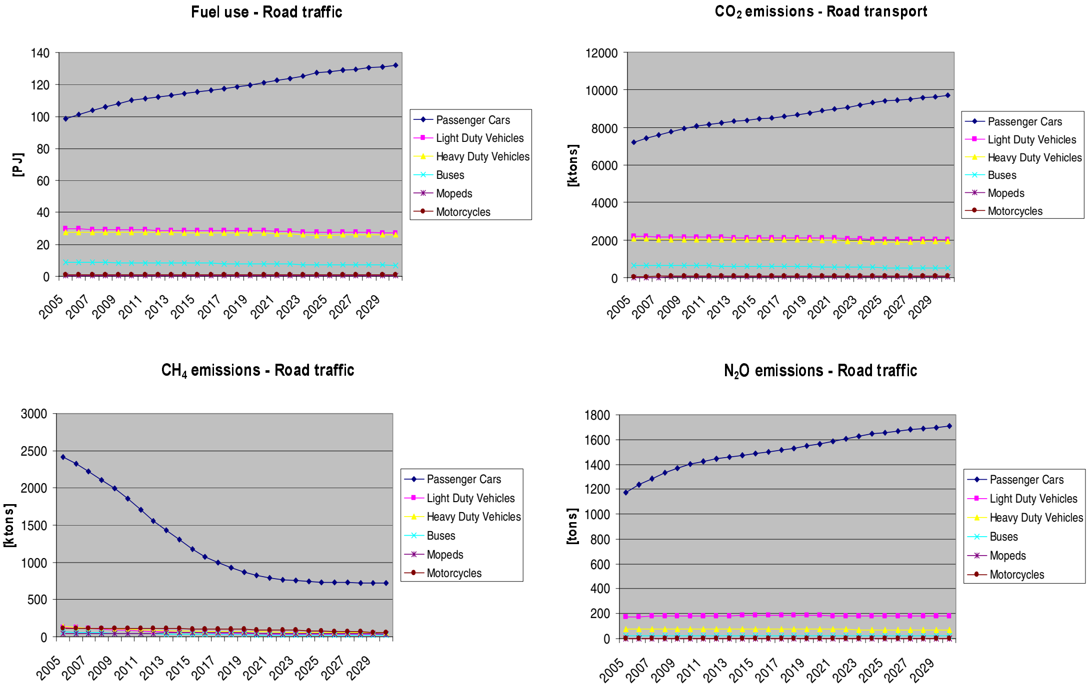

Figure 5.3 Fuel use, CO_2, CH_4 and N_2O emissions from 2005-2030 for road traffic

The total fuel use for road traffic increases by 17% from 2005 to 2030. Passenger cars have the largest fuel use share, followed by heavy duty vehicles, light duty vehicles, buses and 2-wheelers in decreasing order. Heavy duty vehicles and buses have similar fuel use totals, and the fuel use levels are considerably higher than noted for buses and 2-wheelers in particular. The CO_2 emissions directly depend of the fuel use and hence the CO_2 emission trends follow the development in fuel use.

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 68% from 2005 to 2030 is explained by the introduction of gradually more efficient catalytic converters for gasoline cars. The use of catalysts is also the main reason for the total N_2O emission increase of 36% during the same time period. The N_2O emission trend becomes very similar to the fuel use development when the phase out rate of conventional gasoline cars becomes zero.

5.3.2 Other mobile sources

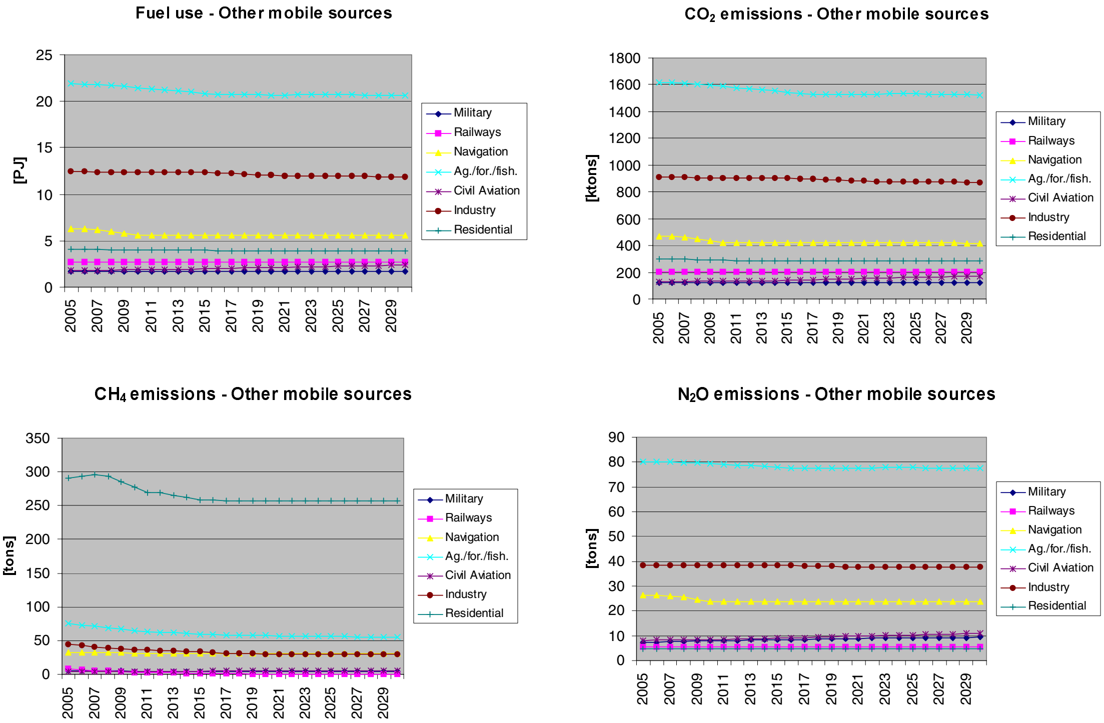

Figure 5.4 Fuel use, CO_2, CH_4 and N_2O emissions from 2005-2030 for other mobile sources

For other mobile sources the fuel use and emissions for Agriculture/forestry/fisheries (1A4c) decrease in the first part of the forecast period. The emission reduction is due to a shift towards a smaller number of agricultural tractors and harvesters, with larger engines. For air traffic, the DEA energy projections assumes a similar growth rate for domestic and international flights corresponding to a fuel use increase of 35% from 2005 to 2030. The marginal fuel use decreases 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 emissions, 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.

By far the majority of the CH_4 emission comes 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.

5.4 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, and output fuel use 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 NERI report in 2007, along with flow-chart diagrams.

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6 Fluorinated gases (F-gases)

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

F-gases are powerful greenhouse gases with GWP between 140 and 23,900. F-gases, therefore, receive a great deal of attention in connection with greenhouse gas 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 regulation in this field into consideration. According to the regulations proposed by the EU Commission, they will only have a lowering effect on emissions from mobile air conditioning equipment, while for the remaining application areas the regulations will lead to increased emissions. 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 LUCF.

HFCs comprise a range of substances, of which the following, relevant for Denmark, are approved for inventory under the Climate Convention and 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 are estimated in Denmark in accordance with the trade names for HFC mixtures which are put together from the ‘pure’ HFCs listed in Table 6.1.

Table 6.1 Relationship (percentage weight) between HFCs, as calculated for the Climate Convention ('pure' HFCs) and the HFC mixtures used under trade names in Denmark

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

HFCs are in most widespread use as refrigerants in stationary and mobile air-conditioning and refrigeration systems. A more 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.

6.1 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. For refrigeration and high voltage equipment, the processes 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 2006. 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, please also refer to the Danish Environmental Protection Agency's annual reports produced as a basis for the F-gas inventories.

6.2 Emissions of the F-gases HFCs, PFCs and SF_6 1993-2020 (2030)

Data is available for historic values for F-gas emissions for the period 1993-2004, as well as projected values for the period 2005-2020 as calculated for the Danish Environmental Protection Agency. 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 the 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 2006 report prepared for the Danish Environmental Protection Agency (DEPA) (Danish Environmental Protection Agency, 2006). Moreover, these data have 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 2004 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 greenhouse gases, 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 6.2. 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 1993-2004 have been explained above (the latest reported data are http://cdr.eionet.europa.eu/dk-/Air_Emission_Inventories/Submission_UNFCCC/colrdy8sq). 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 will be used in Denmark. Therefore, the projection on the '5-year level' for F-gases summarised in Table 6.3 starts from 1995. For the projection after 2020, the total projected emission for 2020 is retained.

Table 6.2 Total F-gas emissions in CO_2-equiv. (1 000 tonnes). Historic data: 1993-2004. Projections: 2005-2020.

	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	815.3	13.9	34.7	863.9
2006	837.4	12.2	35.8	885.4
2007	889.1	10.8	36.0	935.8
2008	891.7	10.1	36.2	937.9
2009	873.3	9.6	36.4	919.2
2010	852.9	9.2	36.6	898.7
2011	804.0	8.9	68.9	881.8
2012	740.1	8.6	115.0	863.7
2013	693.7	8.2	125.0	826.9
2014	610.8	7.8	137.5	756.0
2015	535.1	7.3	122.8	665.2
2016	451.4	6.8	95.1	553.3
2017	388.3	6.5	80.2	475.0
2018	302.3	6.1	110.2	418.6
2019	255.1	5.8	79.4	340.4
2020	170.6	5.6	58.9	235.2

Table 6.3 Total emission of F-gases in CO_2-equiv. (1 000 tonnes). Historic data: 1993-2004. Projections: 2005-2020. After 2020, the emission value for 2020 is retained.

CRF-sector	Year	1995	2000	2005	2010	2015	2020	2025	2030
	Note	(1)			(2)	(3)			
2. Industrial processes									
F. Consumption of halocarbons and SF_6		325.6	681.2	863.9	900.3	655.3	235.2	235.2	235.2

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 6.1, the data from Table 6.2 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 2003. In 2001, legislation began to be adopted to control F-gases in Denmark. The legislation involves, from 2001, a tax on use of F-gases; while 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. SF_6, at the beginning of the historic inventory period, 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.

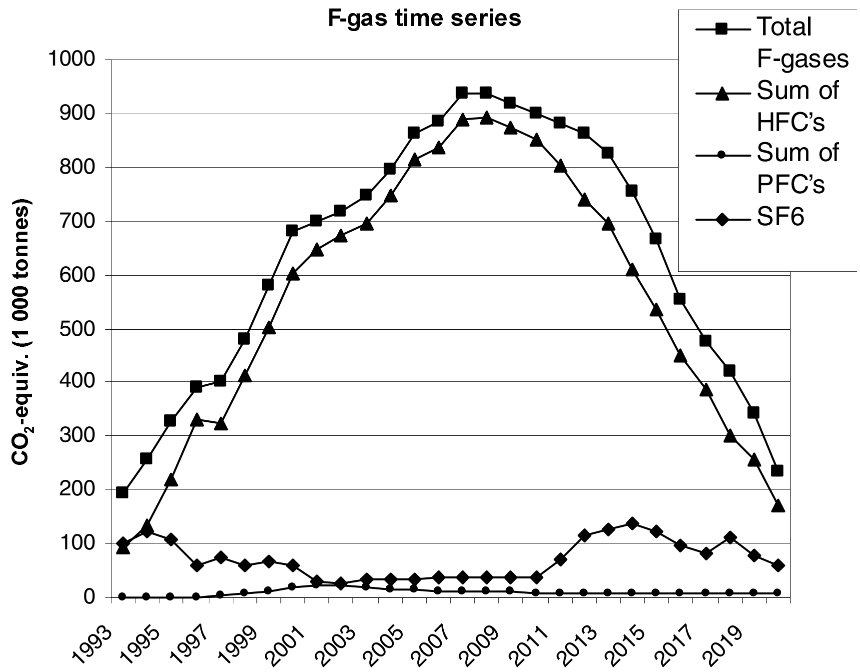

Figure 6.1 Time-series for F-gas emissions, divided into HFCs, PFCs and SF_6

6.3 Emissions of 'pure' HFCs

On the background of the relationship presented in Table 6.1 between HFCs as trade names, as presented in the inventories, and the 'pure' HFCs, reported to the Climate Convention, etc, data is calculated for the 'pure' HFCs, see Table 6.4. In comparison of the HFC total in Table 6.4 with the equivalent in Table 6.2, minor differences are apparent, for reasons as described above. Data from Table 6.4 is, moreover, illustrated in Figure 6.2, except for HFC-32 and HFC-152a, these displaying a relatively low and diminishing share. The largest contribution is from HFC-134a, followed by HFC-143a and HFC-125.

Emissions from use of HFCs as refrigerants dominate (Figure 6.3) in relation to use in foams (Figure 4). Stationary refrigeration equipment, e.g. in supermarkets, constitutes the most common refrigerant application, see Figure 6.3. Otherwise, use is in refrigerators and air conditioning equipment.

The emission from foams is expected to decline over the years as a result of the ban which comes into force in 2006.

Table 6.4 Emissions of 'pure' HFC gases in CO_2-equiv. (1 000 tonnes). Inventories: 1993-2004. Projections: 2005-2020.

	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-total
1993	0.0	0.0	89.7	0.0	4.2	93.9
1994	0.0	0.6	126.6	0.8	6.4	134.5
1995	0.1	7.2	195.1	9.2	6.1	217.7
1996	0.5	26.5	264.9	32.9	4.5	329.3
1997	1.2	44.2	224.1	52.2	2.1	323.8
1998	1.8	61.1	273.8	73.2	1.4	411.2
1999	2.5	88.8	295.7	110.7	5.3	503.0
2000	3.7	120.6	327.3	150.7	2.3	604.6
2001	7.2	136.6	349.4	152.3	1.9	647.3
2002	5.5	135.8	364.8	164.2	1.8	672.1
2003	6.6	153.7	348.8	186.2	0.3	695.5
2004	7.8	167.7	371.9	200.7	0.9	749.0
2005	9.0	191.8	383.3	231.7	0.8	816.6
2006	10.1	213.6	355.3	259.6	0.2	838.7
2007	10.9	230.6	367.3	281.6	0.1	890.5
2008	10.9	231.3	367.6	283.2	0.1	893.1
2009	10.7	228.7	354.7	280.4	0.1	874.7
2010	10.6	225.2	342.7	275.7	0.1	854.3
2011	10.1	208.7	333.3	253.2	0.1	805.4
2012	9.4	194.3	302.6	235.1	0.1	741.5
2013	8.7	180.4	287.6	218.2	0.1	694.9
2014	8.1	163.7	243.3	196.6	0.1	611.8
2015	6.7	140.3	219.1	169.7	0.1	535.9
2016	5.5	116.1	189.7	140.4	0.1	451.8
2017	4.3	97.5	167.1	119.7	0.1	388.7
2018	2.9	69.2	144.1	86.2	0.1	302.5
2019	1.4	50.9	134.2	68.6	0.1	255.2
2020	0.0	21.8	116.2	32.6	0.1	170.6

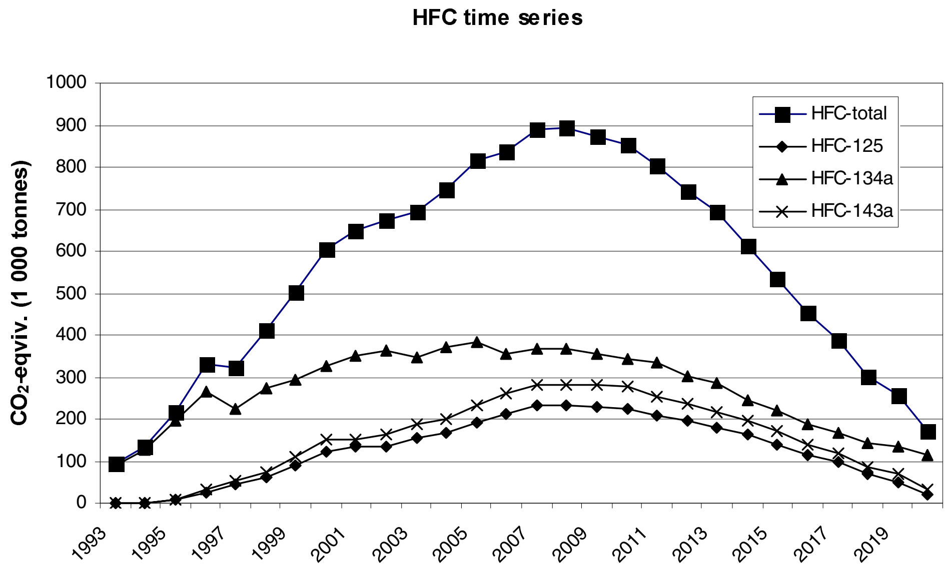

Figure 6.2 Time-series for the emission of 'pure' HFCs

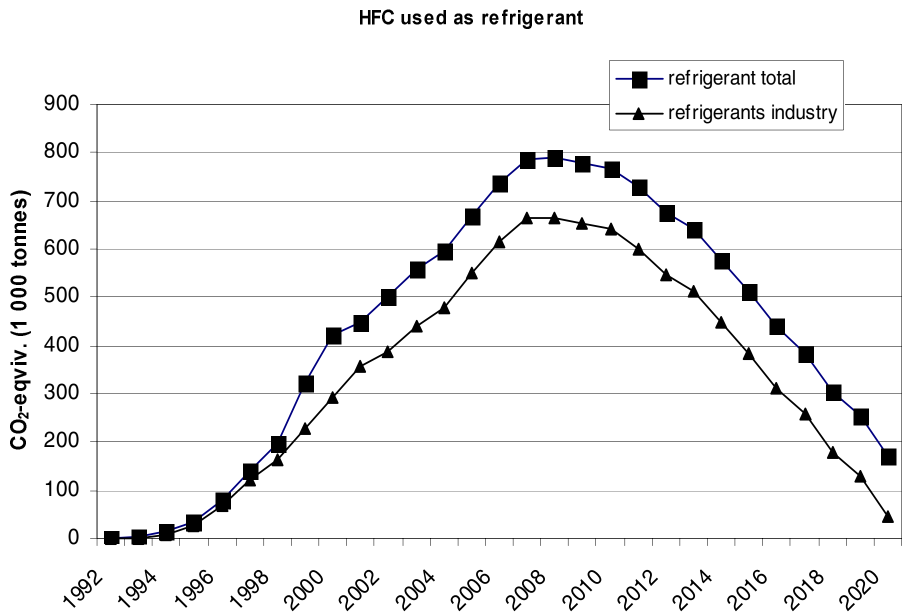

Figure 6.3 Time-series for the emission of 'pure' HFCs used as refrigerants

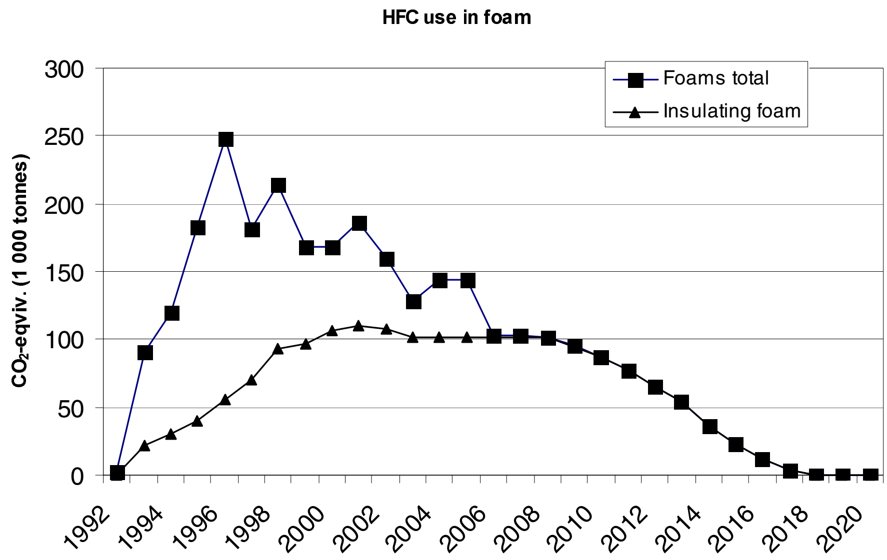

Figure 6.4 Time-series for the emission of 'pure' HFCs used in foams

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7 Agriculture

The emission of greenhouse gases from the agricultural sector includes the emission of methane and nitrous oxide. The emission of carbon dioxide is not included in the projection. The CO_2 emission is not included in Danish reporting under agriculture, but under forestry and land-use change (LULUCF – Land Use, Land Use Change and Forestry). The projection comprises an assessment of the greenhouse gas emissions from the agricultural sector to 2030 – the emissions during 2025-2030 are, however, retained at the same level.

7.1 Projection of agricultural greenhouse gas emissions

Assessment of future greenhouse gas emissions from the agricultural sector is regularly updated in line with actual developments and new scientific knowledge in the area. Therefore, some deviations are apparent in comparison with the projection scenarios published in previous reports. The projections in this publication replace the latest basic projection for greenhouse gases 1990-2017 published in 2004 (Gyldenkærne & Mikkelsen, 2004).

The assumptions which form the base for the updated projections are in many ways the same as those used in earlier projections (Gyldenkærne & Mikkelsen 2004) – however, the emission in the period 1990–2004 has been updated in accordance with the latest official reporting from Denmark. In addition to the ammonia action plan, improvements in feed efficiency, expectations with regard to the increased injection of slurry and the effects of implementation of the Plan for the Aquatic Environment III (VMPIII) have also been taken into consideration, not to mention EU agricultural reform. Moreover, the projections take into account the expectation that emission-reducing technologies will be established. This includes technologies directed at reducing ammonia evaporation in livestock housing units and an increase in the biogas treatment of slurry.

In the period from 1990 to 2004, the emission of greenhouse gases declined from 13,050 ktonnes CO_2 equivalents to 10,000 ktonnes CO_2 equivalents, and it is expected to fall further to 8,690 ktonnes CO_2 equivalents in 2025(30). This means that in the period from 2004 to 2025(30), emissions are expected to fall by 13% – see Table 7.1.

Methane emissions will be reduced as the number of cattle in production falls as a result of the rise in milk yield. The fall in the number of cattle also contributes to a degree to a fall in the nitrous oxide 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 VMPIII. 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 greenhouse gas emission. Both the greenhouse gas emission related to the emission of ammonia and emission reductions from biogas production are relatively minor emission sources, contributing to the total greenhouse gas emission with approx. 4%, in total. At the current time, there are no technical measures in agriculture which are focused directly at reducing greenhouse gas emissions.

Table 7.1 Expected development in the emission of greenhouse gases from the agricultural sector from 2004-2025(30)

	CRF category	Emission of greenhouse gases from the agricultural sector	1990	2000	2004	2005	'2010'	'2015'	2020	2025(30)
CH_4 (Gg)	4A – Enteric Fermentation	Digestive processes	155.19	136.28	129,07	127.66	122.96	116.24	112.08	108.33
	4B - Manure Management	Animal manure	35.90	46.12	47.86	48.96	50.08	49.82	50.05	50.30
	4B- Manure Management	Biogas treatment – slurry	-0.11	-0.68	-1.17	-1.36	-2.22	-2.33	-2.33	-2.33
		CH4, total (Gg)	190.98	181.73	178.10	175.27	170.83	163.73	159.80	156.29
N_2O (Gg)	4B- Manure Management	Animal manure	2.21	1.97	1.85	1.84	1.82	1.80	1.77	1.73
	4B- Manure Management	Biogas treatment – slurry	0.00	-0.03	-0.05	-0.06	-0.10	-0.10	-0.10	-0.10
	4D.1 – Direct Soil Emissions	Commercial fertilisers	7.69	4.83	3.97	3.78	3.52	3.31	3.21	3.13
		Animal manure applied to field	3.51	3.40	3.56	3.61	3.67	3.67	3.66	3.62
		N-fixing crops	0.88	0.76	0.60	0.62	0.61	0.60	0.58	0.57
		Crop residues	1.17	1.09	1.01	1.02	1.00	0.98	0.96	0.94
		Cultivation of organic soils	0.38	0.36	0.35	0.23	0.23	0.23	0.23	0.23
	4D.2 – Animal Production	Grazing	1.01	0.99	0.93	0.94	0.84	0.78	0.76	0.73
	4D.3 – Indirect Soil Emissions	Ammonia evaporation	1.72	1.33	1.22	1.19	1.13	1.07	1.03	1.01
		N-leaching	10.50	7.05	6.49	6.30	5.94	5.63	5.48	5.35
	4D.4 - Other	Wastewater used as fertiliser	0.09	0.17	0.26	0.23	0.22	0.22	0.22	0.22
		N_2O, total (Gg)	29.15	21.92	20.19	19.70	18.89	18.19	17.79	17.44
CO_2-equiv. (million tonnes)		CH_4	4.01	3.82	3.74	3.68	3.59	3.44	3.36	3.28
		N_2O	9.04	6.79	6.26	6.11	5.86	5.64	5.51	5.41
	4. GHG – Agriculture, total	Total - CO_2 equiv. million tonnes	13.05	10.61	10.00	9.79	9.44	9.08	8.87	8.69

7.2 Assumptions for the projection

In this section, a short review of the assumptions is made, which is revised and updated in relation to the earlier projections (Gyldenkærne & Mikkelsen 2004). 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 Plan for the Aquatic Environment III (VMPIII), as well as updating the assumptions for cattle and pig production.

7.2.1 Livestock production

Assumptions made for production of dairy cows and slaughter pigs have been updated. Developments in recent years have shown that milk yield can be assumed to rise more rapidly than assumed in earlier projections. Moreover, the recently approved EU agricultural reform has been assessed to contribute to a slightly higher growth in the production of slaughter pigs than assumed in earlier projections.

Slaughter pigs

More than 80% of Danish pork is exported and production, therefore, is heavily dependent on conditions in the export market. Jacobsen et al. (2003) have assessed that pig production in the period 2001 to 2010 will increase by 1.1% a year; a growth rate considerably lower than that displayed since the beginning of the 1990s. The lower growth rate is due to competition from USA and other European countries, as well as increased import in the domestic market (Jacobsen et al. 2003, Andersen 2002). The EU's agricultural reform (CAP) has now been agreed and will mean, according to Jacobsen et al. (2003), a further 2-3% increase in pig production over the period as a whole, to 2010. This equates to an additional increase of 0.27% per year – i.e. a total of 1.37% per year over the entire period 2001-2010.

Future expansion in production will take place in the larger farm units and, to a degree, will be impeded by the stricter environmental regulations in e.g. VMP III, the Water Framework Directive and the Nitrate Directive (Andersen 2002). Requirements (such as those for a reduction or maintenance of the level of ammonia emissions and smell) form part of many farmers' applications for expanding production (with potential requirements regarding greenhouse gas emissions in future), especially, as would be expected, in areas with sensitive natural habitats. Requirements for reduced emissions can, to some degree, be met via the assistance that technological developments can offer. However, it is doubtful whether technology alone will be able to allow production to grow at the same rate as the development from 1995 to 2004. Therefore, it is assessed that the agricultural reform will contribute to additional growth in pig production, which at the same time will be restricted by increased environmental requirements. In the projection, an increase in production of 1.3% per year is assumed in the period 2001-2015. Thereafter, from 2015-2025(30), the growth rate is estimated to reduce to 0.5% per year. This equates to a rise in pig production from the 23.7 million slaughter pigs produced in 2003 to 27.7 million in 2015, and 29.1 million in 2025(30).

Sows

The development during the period 1995-2003 shows an increase in the number of piglets per sow of 0.3 piglets/sow/year. In the projection, the same development is assumed in the future, to 2025. In 2003, the number of piglets produced was 21.8 per sow. A development of 0.3 piglets/sow/year results in an average production of 25.4 piglets/sow in 2015 and 28.4 piglets/sow in 2025.

Dairy cattle

In the projection to 2030, an increase in the efficiency of dairy yield of 180 kg milk per cow per year is assumed from 2003 to 2015. From 2015 to 2025(30), the rate of increase is not expected to be as high and, in the projection, is assumed to be 100 kg milk per cow per year.

In 2003, average milk yield is 7,900 kg/cow/year (Statistics Denmark (DSt)). An increase of 180 kg milk/cow/year means an average milk yield of 9,200 l/cow/year in 2010 (7,900 kg/cow/year + (7 year * 180 kg/cow/year) and 10,100 kg milk/cow/year in 2015. From 2015, an increase of 100 kg/cow/year is expected, which, in 2025, gives an average milk yield of 11,100 kg milk/cow/year.

The EU milk quota scheme, according to current plans, will be maintained until 2013. Thereafter, however, it is uncertain whether there will be a revised milk quota scheme or whether the scheme will cease to exist altogether for production to function on a world market basis. It is uncertain how Danish milk production will adjust to competition in the world market, but due to the highly intensive production form it is expected that production will not change significantly in relation to current levels. In the projection, it is assumed that the current milk quota will be increased by 1.5% from 2006 and, thereafter, be retained at the same level to 2030. On the basis of a milk quota of approx. 4,790 million kg milk [(7 911 kg/cow/year * 596,034 cows) * (1+0.015)], the number of dairy cows is estimated in 2010, 2015 and 2025(30) as follows:

2010: 4,790 million kg milk / 9,200 kg/cow/year = 520,700 dairy cows

2015: 4,790 million kg milk / 10,100 kg/cow/year = 474,700 dairy cows

2025: 4,790 million kg milk / 11,100 kg/cow/year = 431,500 dairy cows

Bulls and breeding stock

It is assumed that the relationship between dairy cows and bulls is more or less the same from 2003 to 2025(30). It could be assumed that the development in sex quotas for calves will mean a shift in the number of bulls versus breeding stock. However, it is assessed that the overall emission from livestock production will not change considerably as a result of the potential opportunities resulting from sexed semen.

Suckler cows

In the projection to 2030, a fall in the number of suckler cows of 15% is assumed due, in part, to relaxation of the subsidy for male cattle, based on the assessment of Jacobsen et al. (2003). In 2003, 112,000 suckler cows (DSt) were produced and a reduction of 15% results in a production of

95,000 suckler cows in 2010. If the subsidy continues to fall, a further reduction in production can be expected. However, the number of suckler cows has been retained at 95,000 to 2025(30) as the increased requirements for the environmental management of certain areas in connection with the Plan for the Aquatic Environment II (VMPII) schemes, the Water Framework Directive and the Nitrate Directive are likely to lead to greater demand for grazing livestock.

7.2.2 Nitrogen excretion from livestock

The Danish Institute of Agricultural Sciences (DJF) have in connection with VMPIII prepared a paper which states that a further fall in nitrogen excretion (N-excretion) can be expected as a result of increased feed efficiency (Poulsen et al., 2004). On the basis of this, the calculations for nitrogen excretion for cattle and pigs have been updated.

Cattle

According to the default values, N-excretion in 2002/03 for dairy cattle (large breed) was 129.9 kg N/animal/year and, provided there is no change in the improvement of feed, N-excretion is expected to rise to 136 kg N/animal/year. However, a rise in feed efficiency where 25% of farm units are operating at highest efficiency, as well as a reduction in digestible protein, could reduce N-excretion to 123 kg N/animal/year – i.e. a reduction of 5.3%. The development until 2004 shows a more or less stable level for N-excretion as well as a rise in milk yield. A fall in N-excretion occurring at the same time as a rise in milk yield would depend on N-excretion being prioritised as far as research is concerned.

In the projection, it is assumed that it is possible to reduce N-excretion by 5.3% over the years from 2003 to 2025 – i.e. by 4% to 2015 and by a further 1.3% in the period 2015-2025. Based on this, Table 7.2 shows the N-excretion figures used in the projection. It is assumed that the relationships between N ab Animal/N ab Stable and N ab Animal/N ab Storage are the same as in 2003.

Table 7.2 N-excretion for dairy cows – figures used in the projection to 2030

N-excretion dairy cows	2003	2010	2015	2025(30)
	kg N/cow/year	kg N/cow/year	kg N/cow/year	kg N/cow/year
Large breed	130.0	126.9	124.8	123.1
Jersey	107.1	104.6	102.8	101.4

Pigs

Due to the relatively large difference in nitrogen excretion for the best versus the worst farm units, the Danish Institute of Agricultural Sciences (DJF) assesses that in future there will be a significant potential for improving feed efficiency and, thereby, reducing N-excretion. It is, therefore, assumed in the projection that the average in 2025 will be equivalent to the average for 25% of the 'best' (in this respect) farming units today.

By changing feed composition, DJF expect that N-excretion for sows can be reduced from 27.2 to 21.5 kg N/sow/year (a reduction of 21%) – this reduction is based on 23.5 piglets per annual sow. For slaughter pigs, N-excretion is expected to fall from 3.25 to 2.90 kg N/ pig produced /year (a reduction of 11%).

In the projection, it is assumed that the reduction in N-excretion for sows and slaughter pigs will occur over a period from 2003 to 2025. For sows, a lower reduction than that given by DJF is assumed, because, at the same time, a rise in the number of piglets per annual sow is expected. It is assumed that a reduction in N-excretion of 4% in 2015, and 8% in 2025, will occur for sows in relation to the 2003 level. For slaughter pigs, a reduction in relation to the 2003 level of 6% in 2015 and a total of 11% in 2025 is assumed. In Table 7.3, the figures for N-excretion used in the projection in 2010, 2015 and 2025(30) are given.

Table 7.3 N-excretion for pigs – figures used in the projection to 2030

N-excretion for pigs	2003	2010	2015	2025(30)
	kg N/pigs/year	kg N/pigs/year	kg N/pigs/year	kg N/pig/year
Pigs	27.17	26.54	26.08	25.00
Slaughter pigs	3.25	3.14	3.06	2.89

DJF assesses that there is potential for a reduction in N-excretion for other livestock production, but that the reduction will require implementation of a considerable research effort in this area. In the projection, N-excretion for other livestock categories has been retained unchanged at a level equivalent to production conditions in 2003. Cattle and pig production contributes with by far the largest share of the animal manure emission – approx. 80%. The remaining livestock categories are not, therefore, close to being of so much importance in assessing the future total greenhouse gas emission.

7.2.3 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 being included in the projections.

For mink manure, requirements are sharpened in a way corresponding to those for cattle slurry in the first period 2005-2009 – i.e. the projection assumes stricter requirements from 2005. For the remaining livestock categories, N-utilisation is assumed to be increased by 2.5% from 2010 and a further 2% from 2015. This means that 80% of the nitrogen in pig slurry and 75% in cattle slurry will be incorporated in the farmers' fertiliser accounts from 2015.

7.2.4 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% to 2015. This corresponds to a reduction in N-leaching from 164,200 tonnes N in 2003 to approx. 142,800 tonnes N in 2015. This is assumed on the basis that N-leaching in 2020 and 2025(30) is reduced by 15% and 17%, respectively, in relation to 2003 – equivalent to 139,500 kt N in 2020 and 136,200 kt N in 2025(30).

7.2.5 Use of artificial 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 in relation to 2003 – i.e. that the total nitrogen demand per unit of area under cultivation does not change to a marked degree.

Total N-excretion falls from 2003-2025 as a result of improved N-utilisation. Use of nitrogen in artificial fertilisers is predicted to fall by about 20% as a result of the stricter requirements with regard to N-excretion, ammonia-reducing measures in the stable and the fall in land area in agricultural use.

Table 7.4 Expected development in consumption of artificial fertilisers

	2003	2010	2015	2020	2025(30)
			million tonnes N		
N in animal manure (N ab storage)	273	266	262	256	251
N which is included in the farmers' fertiliser accounts	134	142	146	145	144
N in artificial fertilisers	201	183	171	167	163

7.2.6 Agricultural area

Developments from 1985 to 2003 show a fall in agricultural land area of 0.35% per year as a result of urban development in the form of towns and infrastructure, but also due to the afforestation. From 1990 to 2000, on average, 4,000 ha of forest has been planted each year, where a proportion of the area was formerly agricultural land. In the projection, a continued fall in agricultural land area of 0.35% is expected over the period 2003-2015, which is equivalent to 110,000 ha or 9,100 ha per year. Additionally, a further decrease in the area of agricultural land is taken into account for the period 2003-2015 due to the effects of VMPIII, such as increased afforestation and the establishment of wetland areas totalling 30,000 ha. This means that the agricultural land area is expected to fall until 2015 by a total of 140,000 ha (11,600 per year or 0.44% per year) and comprises 2,518 thousand ha in 2015.

2003-2015 – fall in agricultural land area of 140,000 ha (5.2% or 0.44% per year)

- fall of 9,100 ha per year = 110,000 ha
- increased afforestation; 1,500 ha/year = 18,000 ha
- wetland area; 1,000 ha/year = 12,000 ha

2015-2025 – fall in agricultural land area of 86,800 ha (fall of 3.4% as compared with 2015 or 0.35% per year)

Table 7.5 Agricultural land area in the projection

	2003	2015	2020	2025(30)
Agricultural land area (1 000 ha)	2 658	2 518	2 475	2 431

It is not thought that there will be any significant changes in the distribution of crop types in relation to the distribution in 2003. The area of set-aside is not expected to be affected either by the requirements of VMPIII for increased area for the establishment of wetlands and buffers along watercourses and lakes.

7.2.7 Technology

Structural developments have caused a reduction in the number of farm units, but an increase in their size and the trend is likely to continue. Danish Agriculture (Dansk Landbrug, 2004) predicts that, in 2015, an average full-time farming unit will be of 160 ha – i.e. almost double the area under prevailing conditions today – and that the number of farm units will fall from 48,600 in 2003 to 31,600 in 2015. In connection with the predicted increase in farm size, a number of farm units in some geographic locations will be subject to the requirement that environmental impact be reduced or maintained at the same level as under the production level prevailing at the time. This will mean that the demand for existing technological solutions to reduce environmental impact will rise, as well as those technologies made possible in future. This will be especially relevant for units wishing to increase their production in sensitive areas or close to vulnerable habitat types.

Biogas production

The use of liquid slurry in the production of biogas will contribute to a reduction in the emission of methane as well as nitrous oxide.

In the Danish Energy Authority's latest projections from April 2005, a positive development in biogas production is expected (Energistyrelsen 2005). At present, approx. 5% of liquid slurry is used in biogas production, equivalent to approx. 1.6 million tonnes liquid slurry and, according to the energy projections, this is expected to rise to 4 million tonnes in 2010 (Søren Tafdrup, pers. comm.). This will mean a reduction in the greenhouse emission of 0.08 million tonnes CO_2 equivalents in 2010 (Table 7.6). In the projection, no further extension of the use of liquid slurry in biogas production is assumed from 2010 to 2025(30).

Table 7.6 Expected development in liquid slurry used in biogas production

	Million tonnes liquid slurry used in the production of biogas	Reduced emission		
		Gg CH_4	Gg N_2O	Million tonnes CO_2-equiv.
2003	1.6	0.93	0.04	0.03
2004	2.0	1.17	0.05	0.04
2010(30)	4.0	2.33	0.10	0.08

Current biogas production corresponds to approx. 5% of the slurry being treated to produce biogas and the effect estimated is assessed to contribute to a reduction in the total greenhouse gas emission of less than 0.5%.

Technologies to reduce ammonia emissions

Currently, the use of technologies to reduce ammonia emissions is limited and is estimated to occur in less than 1% of total livestock production. These technologies are primarily directed towards the reduction of ammonia evaporation, which does not itself have a direct effect on greenhouse gas emissions. It does, however, have an indirect effect as the nitrous oxide emission is closely linked with the nitrogen cycle. In the projection, it has been decided to include the effects from ammonia-reducing technologies for dairy cows and slaughter pig production, these being the most important for total livestock production.

Dairy cow production

In 2003, according to Statistics Denmark, there were 596,000 dairy cows, of which 63% are estimated to be housed in stable systems with cubicles, equating to 375,000 dairy cows. Almost all dairy cattle in 2015 are expected to be housed in cubicle systems. I.e. for the 475,000 dairy cows expected in 2015, new cubicles will have to be built for approx. 100,000 cows. It is assumed that approx. 20% of the existing stables will have to be replaced – i.e. approx. 75,000. It is, therefore, assumed that between 2003 and 2015, new stabling will have to be built to house approx. 175,000 new cubicles.

Reduced numbers of farming units means existing production within the individual units will expand. In many cases, requirements for reduced environmental impact will apply, including requirements with regard to ammonia evaporation from e.g. livestock housing. In the projection, it is assumed that a requirement for a 50% reduction in ammonia evaporation from the stable during manure storage and application will apply to half of the 175,000 new housing places. I.e. the requirement will cover 85,000 dairy cows, equivalent to approx. 20% of the total production in 2015. To 2025, it is estimated that requirements with regard to the application of reduction technologies will apply for 30% of total production.

Existing technologies currently focused on reducing ammonia evaporation in dairy stables are treatment of slurry with sulphuric acid and the establishment of prefabricated, solid, drained floors, which are expected to be able to reduce evaporation in the stable by 50% compared with stables with slatted floors (BAT 107.04-51 and 107.04-52). It cannot, however, be ruled out that other technologies with greater reduction potentials may be brought into use at a later date. Treatment of slurry with sulphuric acid will mean that a greater proportion of the nitrogen in the slurry will be retained in ammonium-form, which is by far less volatile than ammonia. This means that ammonia evaporation is also reduced under storage and under application of animal fertilisers.

Slaughter pig production

Slaughter pig production is predicted to increase from 23.7 million slaughter pigs in 2003 to 27.7 million slaughter pigs in 2015, i.e. an increase of 4 million slaughter pigs. It is assumed that the proportion of pigs on partially slatted flooring will increase from 35% in 2003 to 50% in 2015 – i.e. production of a further 5.5 million pigs. This means an increase in the number of new stables for production of 9.5 million pigs. Moreover, replacement of stable housing for 30% of the existing production, corresponding to 5.5 million pigs, is assumed. I.e. a total requirement is foreseen for new stabling for production in the region of 15 million slaughter pigs.

In the projection, it is assumed that for half of this production in new stabling, there will be requirements set for the implementation of technologies for the reduction of ammonia evaporation in the stable by 70% – i.e. applying to 7.5 million finished slaughter pigs. This equates to the establishment of technology for approx. 30% of total slaughter pig production in 2015. It is assumed that the establishment of reduction technologies will apply to 40% of production in 2015.

Good opportunities exist for ammonia limiting measures in pig housing. Chemical and biological air-cleaning is currently installed in around 30 housing units and acid cleaning equipment has similarly been installed in at least 30 housing units. Depending on the air cleaning system selected, it is predicted that ammonia evaporation can be reduced by between 60-95% (BAT 106.04-58, BAT 106.04-57, Danske Slagterier 2004, Landscentret 2002 and 2005). Sulphuric acid treatment equipment for pig slurry in stable systems with partially slatted floors is predicted to be able to reduce ammonia evaporation in the stable by 80% (BAT 106.04-54). In the projection, an average reduction factor of 70% is used in the stable, under storage and field application.

Table 7.7 Predictions regarding establishment of ammonia-reducing technology in the stable

	2015	2025
	Share of production with reduction technology	Share of production with reduction technology
Dairy cattle (50 % reduction)	20%	30%
Slaughter pigs (70% reduction)	30%	40%

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

In the projection, the greenhouse gas emission is expected to fall from 10.00 million tonnes CO_2 equivalents in 2004 to 8.69 million tonnes CO_2 equivalents in 2025(30) – corresponding to a fall of 13%. The reduction in the methane emission will occur as a result of the fall in the number of cattle which, in turn, stems from rising milk yields. The reduction in nitrous oxide emission is due mainly to a reduction in N-leaching, stemming from the effects of VMPIII and a fall in the use of artificial fertilisers, resulting, in turn, from improvements in the utilisation of nitrogen in animal manure and the fall in land area under agricultural cultivation.

Establishment of certain technical measures, such as ammonia-reducing measures in the stable and expansion of biogas production, is taken into account. As the ammonia emission, however, is just one of the more minor sources of the nitrous oxide emission, a reduction will have limited effect on total greenhouse emissions. Ammonia evaporation is one of many sources of greenhouse gas emissions, contributing with less than 4% of total emissions. Therefore, a marked reduction in ammonia evaporation e.g. 10% in 2004, assuming that the remaining sources of emissions are maintained at the same level, would give a somewhat smaller reduction in the total greenhouse emission of 0.4%. A fall in ammonia evaporation can, however, have a positive bonus effect for the total emissions as an improvement in the nitrogen utilisation of manure will lead to a reduction in the emission from other sources.

Biogas-treated slurry contributes in 2003 to a reduction of 0.04 million tonnes CO_2 equivalents. Therefore, to achieve a significant effect on the total emission, 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 which are specifically aimed towards limiting greenhouse gases.

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8 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 is annual data for the amount of waste deposited and where emissions factors, which are the amounts of CH_4 emitted per amount of waste deposited, result from model assumptions about the decay of waste and release of CH_4.

8.1 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 plant 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 DEPAeach year, by 31 January at the latest. The report for 2004 is number twelve. The results of this reporting are published in the form of annual waste statistics, 2004 being the latest year; see DEPA (Miljøstyrelsen), 2005a. Reports before this latest report are DEPA (2004a) and DEPA (2004b).

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

8.2 Emissions model

The model has been developed and used in connection with the historic emissions inventories prepared for the 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). On the recommendation of these reports, a so-termed Tier 2 method, a decay model, has been selected for the model. The model is described in the report which is prepared for the Climate Convention, the latest being the 2006 NIR report. 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 carbon has been converted to 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 emissions inventories. The model is built in one file in Microsoft Excel.

8.3 Historic emissions

In connection with greenhouse gas inventories for the Climate Convention, a so-named key-source analysis is carried out. The analysis aggregates CO_2, CH_4, N_2O and the F-gases in relation to their respective greenhouse gas potentials, and lists these on a source level in relation to the Danish national total figures for greenhouse gas emissions. In an analysis of this type, carried out most recently in 2004, the CH_4 emission from the landfill of waste is categorised as a key-source. This is because this source, out of the 71 sources the analysis comprises, belongs to the 21 largest sources whose greenhouse gas emissions totals comprise 95% of the national total. The landfill of waste is calculated to rank as no. 10 in size among the 21 key sources. The CH_4 emission from landfill sites comprised 1.6% of the national total in 2003. 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.

8.4 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 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 waste strategy's reported distribution (%) by sector of waste deposited at landfill is presented for 2001 in Table 8.1, along with the targets for 2008.

Table 8.1 Share (%) of total landfill

	Distribution 2004	Target 2008
Household waste	1	0
Large items of waste	19	25
Garden waste	1	0
Waste from institutions, commerce and offices	8	5
Industry	24	15
Construction	4	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 in the Department of Policy Analysis at the research centre, Risø (Miljøstyrelsen (2006)). The model is a further development of the model described in the report from DEPA (Miljøstyrelsen, 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 waste produced for 2008 calculated as described, waste amounts for 2008 are then calculated on the basis of the same distribution as registered in 2003. The amount of waste for the respective waste fractions is, thereafter, interpolated between the registered values for 2003 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 8.2 and Figure 8.1. 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 Authority'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 (Miljøstyrelsen, 2005b), the firm LFG-Consult (H. C. Willumsen) has reviewed Danish landfill sites and, in this connection, scenarios for methane recovery have been prepared for the years 2005-2009. In the projections in hand, Table 8.2, a scenario (Miljøstyrelsen, 2005b) has been used without optimisation of landfill sites. For the period 2010-2030, an exponential extrapolation has been carried out; see Figure 8.2.

The overall projection is shown in Table 8.3.

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, and 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 8.2 Amount of waste deposited at landfill and CH_4 emissions. Historic data: 1993-2004. Projections: 2005-2030.

Year	Quantities of waste (1 000 tonnes)									Emissions (1 000 tons CH_4)			
	House hold waste	Large items	Garden Waste	Institu tions Commerce and offices	Industry	Con-struc-tion	Sewage sludge	Slags	Total	Potential	Actual gross	For biogas	Net
1990	199	251	85	109	822	951	222	535	3175	85,2	64,0	0,5	63,5
1991	199	259	71	120	824	804	193	562	3032	83,7	65,3	0,7	64,6
1992	198	267	56	131	826	657	165	589	2890	82,2	66,5	1,4	65,1
1993	198	276	42	141	828	510	136	616	2747	80,7	67,4	1,7	65,7
1994	198	284	27	152	830	363	107	643	2604	79,2	68,2	4,6	63,6
1995	190	286	17	128	779	321	101	135	1957	74,7	68,7	7,4	61,2
1996	132	275	6	135	822	317	117	703	2507	71,4	68,8	8,2	60,7
1997	83	248	6	170	707	264	130	475	2083	65,9	68,6	11,1	57,5
1998	98	234	20	161	746	266	124	210	1859	66,3	68,5	13,2	55,3
1999	117	239	3	164	582	224	126	12	1467	63,5	68,2	11,5	56,7
2000	85	264	7	152	611	269	94	0	1482	62,5	67,8	11,0	56,8
2001	50	180	3	150	583	260	64	10	1300	49,9	66,6	10,0	56,6
2002	37	161	4	137	520	229	48	38	1174	43,9	65,1	11,2	53,9
2003	24	143	4	131	379	170	55	60	966	37,6	63,2	7,8	55,4
2004	11	132	5	140	452	172	42	46	1000	37,5	61,5	10,4	51,1
2005	16	146	5	148	464	185	50	54	1070	40,6	60,1	7,3	52,8
2006	21	161	5	157	477	198	57	63	1139	43,7	59,0	6,9	52,1
2007	27	175	5	165	489	212	65	71	1209	46,7	58,2	6,5	51,7
2008	32	189	5	173	502	225	73	79	1278	49,8	57,6	6,0	51,6
2009	32	191	5	175	505	227	73	80	1288	50,2	57,1	5,7	51,4
2010	32	189	5	174	502	225	73	79	1280	49,9	56,6	5,3	51,3
2011	32	192	5	176	510	229	74	81	1299	50,6	56,2	5,0	51,2
2012	33	194	5	177	513	230	74	81	1308	51,0	55,9	4,7	51,1
2013	33	196	5	180	520	233	75	82	1325	51,6	55,6	4,5	51,1
2014	33	197	6	180	522	234	76	83	1330	51,8	55,3	4,3	51,1
2015	33	199	6	183	528	237	77	84	1346	52,4	55,2	4,1	51,1
2016	33	200	6	183	529	237	77	84	1348	52,5	55,0	3,9	51,0
2017	34	200	6	184	531	238	77	84	1354	52,7	54,8	3,8	51,0
2018	34	202	6	185	534	240	78	85	1362	53,1	54,7	3,6	51,1
2019	34	202	6	185	535	240	78	85	1365	53,2	54,6	3,5	51,1
2020	34	204	6	187	540	242	78	86	1377	53,7	54,5	3,4	51,1
2029	34	204	6	187	540	242	78	86	1377	53,7	54,0	2,8	51,2
2030	34	204	6	187	540	242	78	86	1377	53,7	53,9	2,7	51,2

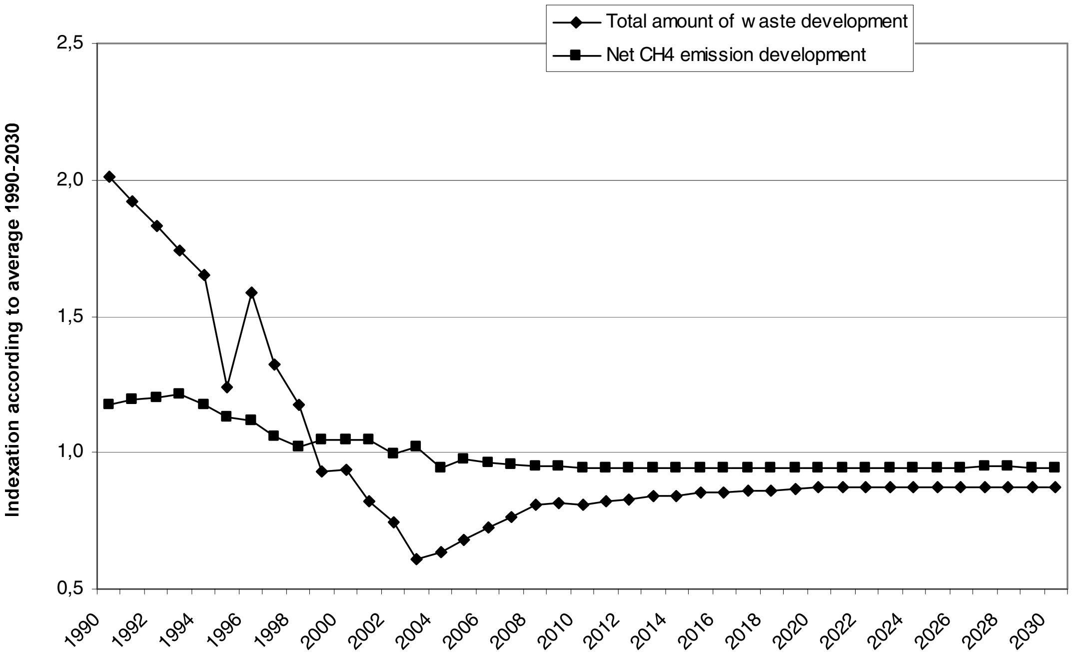

Figure 8.1 Development of waste deposited at landfill and CH_4 emissions. Historic data: 1993-2004. Projections: 2005-2030. Indexation is in relation to the time series average for the relevant parameter.

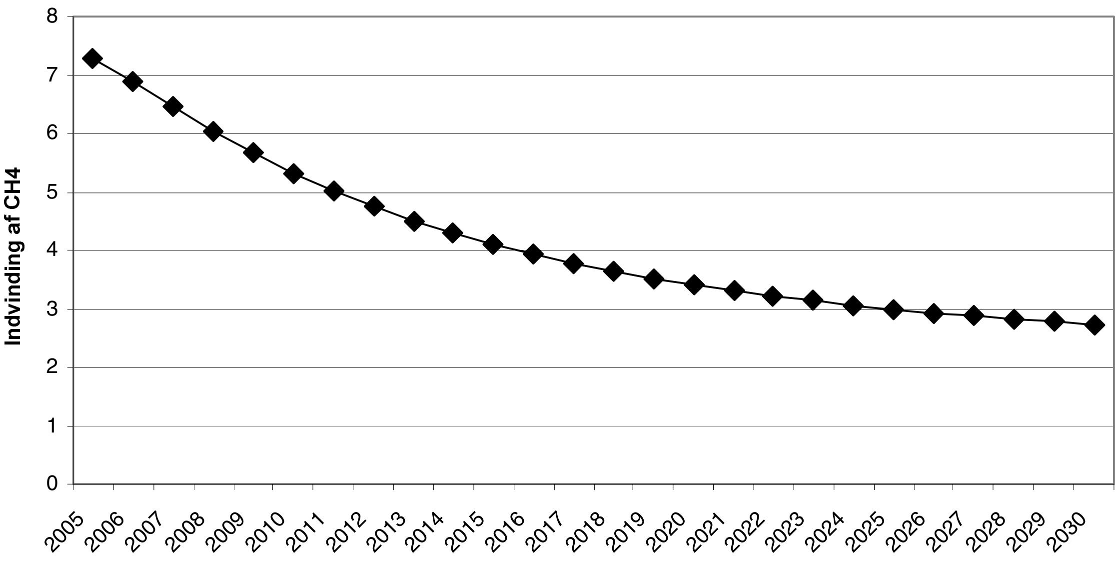

Figure 8.2 Projection of CH_4 recovery at landfill sites (1 000 CH_4 tonnes). For 2005-2009 data according to Danish Environmental Protection Agency (Miljøstyrelsen 2005b). For 2009-2030: exponential extrapolation.

Table 8.3 Emission of CH_4 from landfill of waste in CO_2-equiv. (1 000 tonnes =Gg). Historic data: 1993-2004. Projections: 2005-2020.

CFR sector	Year Note	1990	2000	2005	2010 (1)	2015 (2)	2020	2025	2030
6. Solid waste disposal on Land									
1. Managed waste disposal on land		1334,1	1192,3	1109,0	1078,3	1072,3	1073,8	1077,1	1075,2

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

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Regeringen, 2003: Affaldsstrategi 2005-2008.

9 Wastewater treatment

Below, a short overview of the emissions inventories of methane and nitrous oxide from wastewater treatment 1990-2004 is provided, as well a projection to 2030.

In short, the emission calculations for methane are based on the theoretical maximum emission termed, here, 'gross methane emission'. This gross emission is based on the emission from the entire methane potential in the amount of biodegradable organic material in the discharges entering the sewage treatment plants. From this theoretical maximum emission, the methane potential which is used for biogas and other reuse or flared is deducted. The resulting net methane emission is an estimate of the real methane emission in wastewater treatment at sewage works. Central parameters are the industrial contribution to wastewater entering wastewater treatment plants as well as the fraction of sewage sludge which is treated anaerobically. For a detailed review of calculation methodologies, refer to the report Thomsen, M and Lyck, E (2005).

Emission calculations for nitrous oxide are divided into the contribution from the wastewater treatment processes at the sewage plants, termed the direct emission, and a contribution from the discharge from the treatment plants, termed the indirect N_2O emission.

Table 9.1 Gross, retained (re-used or flared) methane potentials and net emission of methane from 1990 to 2030 in Gg.

	Estimated values					
Year	$CH_{4,\ external\ combustion}$	$CH_{4,\ internal\ combustion}$	$CH_{4,\ sandblasting\ materials}$	$CH_{4,\ biogas}$	$CH_{4,\ gross}$	**$CH_{4,\ net}$**
1987	2.34	4.79	1.15	0.08		
1990	2.39	4.67	1.20	0.24	14.42	**5.91**
1991	2.41	4.60	1.34	0.27	14.46	**5.84**
1992	2.43	4.52	1.49	0.30	14.51	**5.78**
1993	2.44	4.44	1.63	0.32	14.91	**6.07**
1994	2.46	4.36	1.78	0.35	16.20	**7.24**
1995	2.47	4.29	1.92	0.38	17.49	**8.43**
1996	2.49	4.21	2.07	0.40	18.79	**9.62**
1997	2.19	4.42	1.23	0.46	20.10	**11.81**
1998	2.52	4.05	2.36	0.45	21.42	**12.03**
1999	2.25	4.29	2.67	0.55	21.04	**11.28**
2000	3.64	3.12	3.61	0.51	21.22	**10.34**
2001	2.74	4.28	3.19	0.43	21.65	**11.02**
2002	1.91	3.47	2.87	0.41	23.43	**14.78**
2003	2.07	4.13	3.08	0.42	24.03	**14.26**
2004	2.07	4.13	3.23	0.39	22.96	**12.61**
2005	2.07	4.13	3.37	0.39	22.96	**12.06**
2006	2.07	4.13	3.52	0.39	23.24	**11.72**
2007	2.07	4.13	3.66	0.39	23.52	**11.28**
2008	2.07	4.13	7.75	0.39	23.81	**10.75**
2009	2.07	4.13	7.75	0.39	24.09	**10.09**
2010	2.07	4.13	7.75	0.39	24.37	**10.03**
2011	2.07	4.13	7.75	0.39	24.65	**10.31**
2012	2.07	4.13	7.75	0.39	24.94	**10.60**
2013	2.07	4.13	7.75	0.39	25.22	**10.88**
2014	2.07	4.13	7.75	0.39	25.50	**11.16**
2015	2.07	4.13	7.75	0.39	25.79	**11.44**
2016	2.07	4.13	7.75	0.39	26.07	**11.73**
2017	2.07	4.13	7.75	0.39	26.35	**12.01**
2018	2.07	4.13	7.75	0.39	26.63	**12.29**
2019	2.07	4.13	7.75	0.39	26.92	**12.58**
2020	2.07	4.13	7.75	0.39	27.20	**12.86**
2021	2.07	4.13	7.75	0.39	27.48	**13.14**
2022	2.07	4.13	7.75	0.39	27.77	**13.42**
2023	2.07	4.13	7.75	0.39	28.05	**13.71**
2024	2.07	4.13	7.75	0.39	28.33	**13.99**
2025	2.07	4.13	7.75	0.39	28.62	**14.27**
2026	2.07	4.13	7.75	0.39	28.90	**14.56**
2027	2.07	4.13	7.75	0.39	29.18	**14.84**
2028	2.07	4.13	7.75	0.39	29.46	**15.12**
2029	2.07	4.13	7.75	0.39	29.75	**15.41**
2030	2.07	4.13	7.75	0.39	30.03	**15.69**

Based on interpolation for reported data, the methane potential converted via external combustion is assessed to be constant, while for internal combustion it is assessed to decline slightly over the period 1987-2002. The total amount of sewage sludge incinerated aligns with the government's target for 2008. The projections assume that the total amount of sewage sludge which is incinerated remains constant at present levels. The rise in retained methane potential is expected to be due to increased reuse of sludge in industrial processes (see the government waste strategy, Regeringen, 2003; Thomsen and Lyck, 2005).

The emission calculations are based on data from private and local authority wastewater treatment plants included in the national reports from the Danish Environmental Protection Agency (Thomsen and Lyck, 2005). Any methane emission contribution from wastewater treatment in individual industries is not included in the calculations.

The trend from 1990 to 2005, as well as the regression equations used in the projection to 2030, is shown in Figure 9.1.

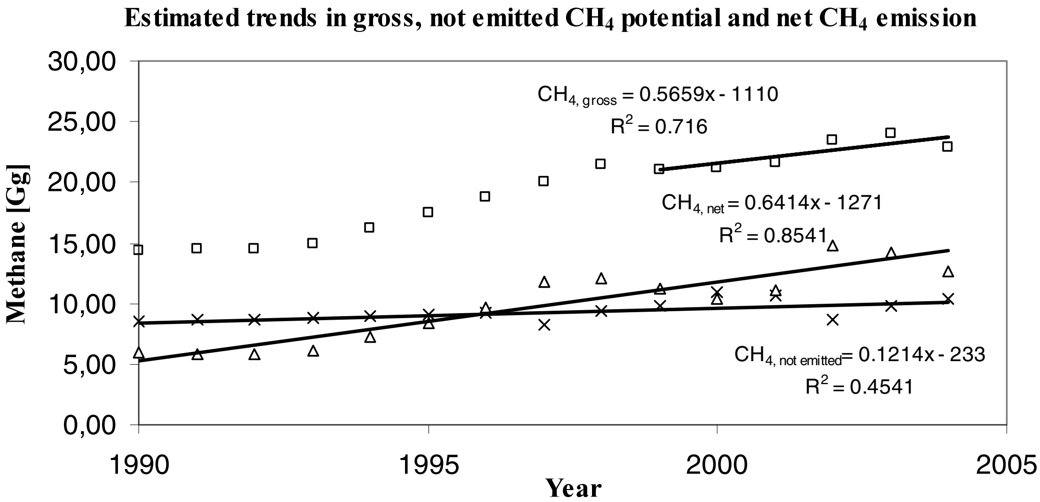

Figure 9.1 Estimated trends in gross, retained (i.e. recycled or flared) CH_4 potential, and the resulting net CH_4 emission. For use in the projection of the gross emission of methane, the period from 1999 has been used, from which point the contribution of industry to the amount of total organic material at the local authority treatment works is constant and the rise in the gross emission is caused by a real increase in the total amount of organic material in the wastewater entering the works. The curved sequence represented by open squares and white triangles represent the gross and net emission of methane, respectively. The curved sequence represented by crosses represents the total amount retained (recycled or flared) methane potential.

The emission of N_2O from wastewater treatment plants is divided into a direct emission, from biological treatment processes at the treatment works, and an indirect emission, from the nitrogen which exits the works in the wastewater effluent discharged. The total emission of nitrous oxide is the sum of these two contribution types.

Table 9.2 Estimated direct, indirect and total emissions of N_2O in tonnes.

Year	Average, $E_{N2O,WWTP,direct}$ (Danish EF)	E_{N2O}, effluent in total Tonne	E_{N2O}, total [T]
1990	17.37	265.32	282.69
1991	17.41	251.93	269.34
1992	17.47	219.26	236.73
1993	19.73	273.48	293.20
1994	29.09	268.38	297.47
1995	36.65	238.10	274.76
1996	44.28	179.63	223.91
1997	51.96	158.21	210.17
1998	58.69	153.94	212.63
1999	52.59	147.13	199.72
2000	53.66	157.22	210.88
2001	50.20	134.40	184.60
2002	50.32	137.34	187.67
2003	51.69	144.03	195.72
2004	52.36	144.03	196.39
2005	52.48	144.03	196.51
2006	52.59	144.03	196.62
2007	52.70	144.03	196.72
2008	52.79	144.03	196.82
2009	52.88	144.03	196.91
2010	52.96	144.03	196.99
2011	53.04	144.03	197.06
2012	53.10	144.03	197.12
2013	53.15	144.03	197.18
2014	53.20	144.03	197.23
2015	53.25	144.03	197.27
2016	53.29	144.03	197.31
2017	53.33	144.03	197.36
2018	53.37	144.03	197.40
2019	53.41	144.03	197.44
2020	53.46	144.03	197.48
2021	53.50	144.03	197.53
2022	53.55	144.03	197.57
2023	53.59	144.03	197.62
2024	53.64	144.03	197.66
2025	53.68	144.03	197.70
2026	53.72	144.03	197.74
2027	53.75	144.03	197.77
2028	53.77	144.03	197.80
2029	53.79	144.03	197.82
2030	53.80	144.03	197.83

Calculation of the direct emission and projections are based on population size as well as on a calculation methodology for emissions factors, which is corrected for industry's contribution to the N in the wastewater entering the sewage treatment works. Generally, the industrial contribution is assumed to be constant from 1999 and thereafter. The emission contribution from industry is set at 41.9 % (the average of the contribution in the years 1999-2002) for both projections. Nitrous oxide production takes place under anaerobic as well as aerobic conditions (nitrification and denitrification), but its generation is most pronounced under aerobic conditions. The nitrous oxide emission is expected to remain at a constant level due to the fully optimised cleaning of wastewater effluent which has occurred in connection with the plans for the aquatic environment. The estimated trend in indirect and direct nitrous oxide emission from 1990 to 2030 is illustrated graphically in Figure 9.2 and 9.3.

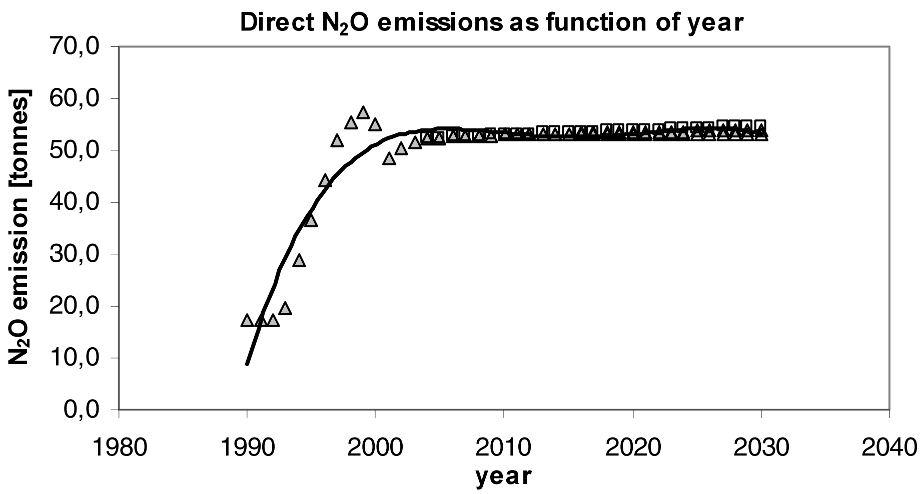

Figure 9.2 Trend for direct nitrous oxide emissions from wastewater treatment processes at sewage treatment works. The observed maximum in 1998 cannot be regarded as actual, but a visualisation of the measured data, which is not representative. This explains the relatively large uncertainty in the average national data for the content of nitrogen in wastewater entering sewage treatment works.

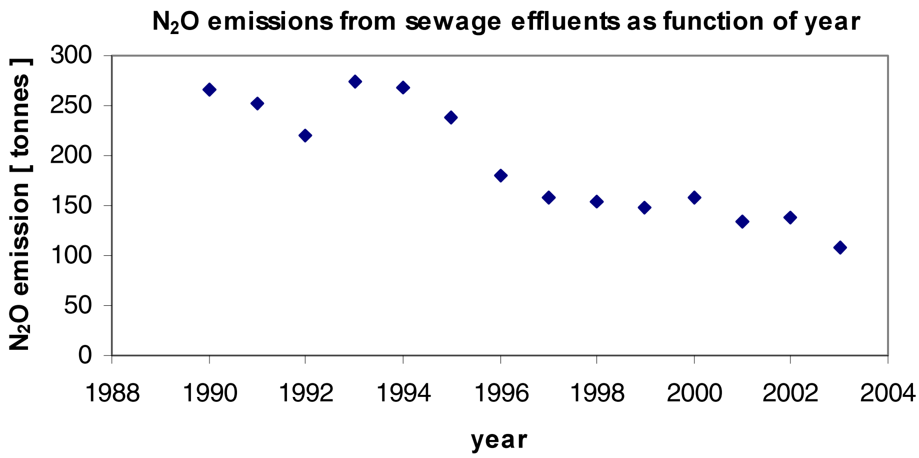

Figure 9.3 Trend for indirect nitrous oxide emissions. The declining trend is due to the results of technological development and the improvement in the treatment processes at sewage works in the form of an increased reduction of P, N and BOD in biological and chemical treatment processes for discharge. The reduction in the discharge of nitrogen is not expected to fall further.

Total N_2O and net CH_4 emission figures converted to CO_2 equivalents are given in Table 9.3.

Table 9.3 N_2O and CH_4 emissions in CO_2 equivalents and the unit Gg. Inventories: 1990-2004. Projections: 2005-2030

	Emissions in CO_2-equiv. (Gg)	
Year	N_20	CH_4
1990	87.63	125.62
1991	83.50	122.60
1992	73.39	121.29
1993	90.89	127.49
1994	92.22	152.13
1995	85.17	176.97
1996	69.41	202.01
1997	65.15	248.11
1998	65.92	252.60
1999	61.91	236.86
2000	65.37	217.19
2001	57.23	231.45
2002	58.18	310.29
2003	60.67	299.40
2004	60.95	264.72
2005	60.99	253.22
2006	61.02	246.05
2007	61.06	236.98
2008	61.09	225.73
2009	61.11	211.98
2010	61.14	210.62
2011	61.16	216.56
2012	61.18	222.50
2013	61.20	228.45
2014	61.21	234.39
2015	61.23	240.33
2016	61.24	246.27
2017	61.25	252.21
2018	61.27	258.15
2019	61.28	264.10
2020	61.29	270.04
2021	61.31	275.98
2022	61.32	281.92
2023	61.33	287.86
2024	61.35	293.81
2025	61.36	299.75
2026	61.37	305.69
2027	61.38	311.63
2028	61.39	317.57
2029	61.40	323.52
2030	61.40	329.46

Table 9.4 Sum of the emission of CH_4 and N2O from wastewater treatment in CO_2 equivalents (1 000 tonnes =Gg).

CFR sector	Year	1990	2000	2005	2010	2015	2020	2025	2030
	Note				(1)	(2)			
6.B Waste water handling		213.2	282.6	314.2	278.6	301.6	331.3	361.1	390.9

Note	(1)	5-year average	2008-2013
	(2)	5-year average	2013-2018

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Thomsen, M. and Lyck, E. (2005): Emission of CH_4 and N_2O from Wastewater Treatment plants (6B). Department of Policy Analysis. National Environmental Research Institute DK-4000 Roskilde. http://www2.dmu.dk/1_viden/2_Publikationer/3_arbrapporter/rapporter/AR208.pdf

Regeringen 2003. Affaldsstrategi 2005-2008.

10 Conclusions

The historic and projected greenhouse gas (GHG) emissions are shown in Tables 10.1 – 10.9 and illustrated in Figure 10.1. Projected GHG emissions include the estimated effects of policies and measures implemented until October 2006, and the projection of total GHG emissions is therefore a so-called 'with measures' projection. The main sectors in 2008-2012 ('2010') are expected to be Energy Industries (39 %), Transport (21 %), Agriculture (14 %), and Other sectors (10 %). For the latter sector the most important sources are fuel use in the residential sector and the agricultural sector (Table 10.1). The GHG emissions show a decreasing trend from 1990 to 2030 and, 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 emission in '2010' is estimated to be 67,800 ktonnes CO_2 equivalents and 60,386 ktonnes in 2030, corresponding to a decrease of about 10%. From 1990 to '2010', the emissions are estimated to decrease by about 2%. 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.

Calculation of the GHG emissions for the various IPCC categories is described in Chapters 2-9, except for emissions from the use of solvents (6). The projected GHG emissions from the use of solvents are based on the 2004 historic emissions and the conversion factor from NMVOC to carbon is assumed to be 0.85.

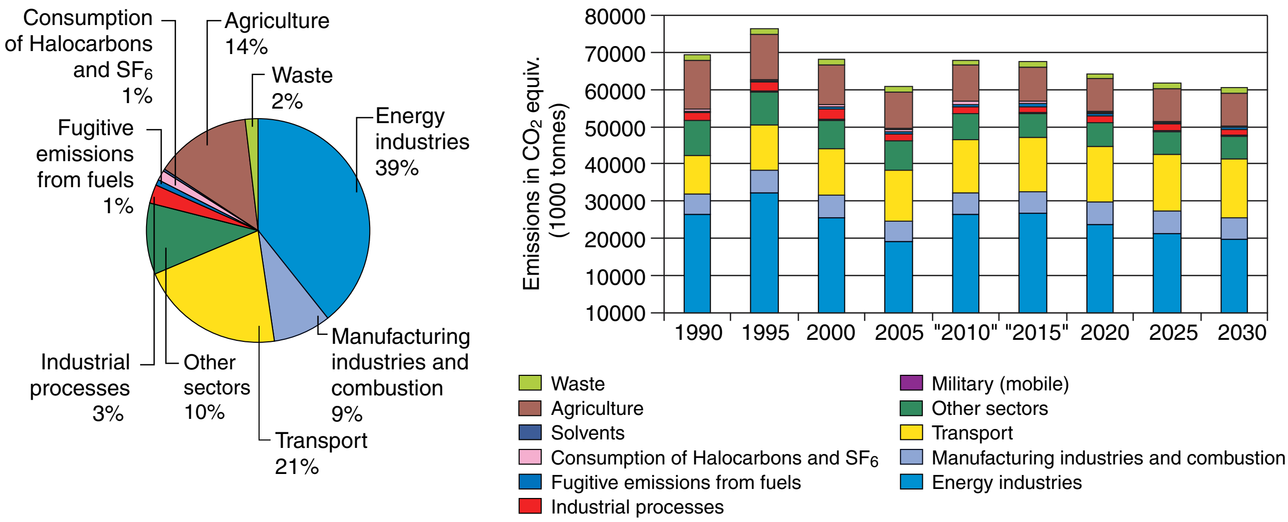


Figure 10.1 Total GHG emissions in CO_2 equivalents. Distribution according to main sectors ('2010') and time-series for 1990 to 2030.

10.1 Stationary combustion

The GHG emissions in '2010' from the main source, which is public power (57%), are estimated to decrease significantly in the period from 2006 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 almost halve 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 more than 300% from 1990 to '2010' and by almost 60% from '2010' to 2030.

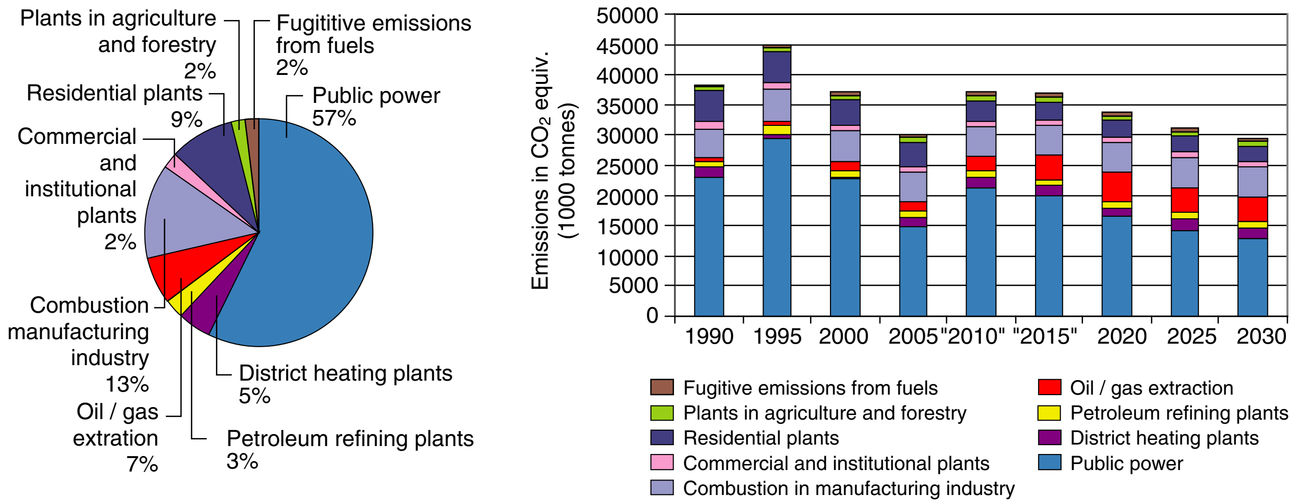
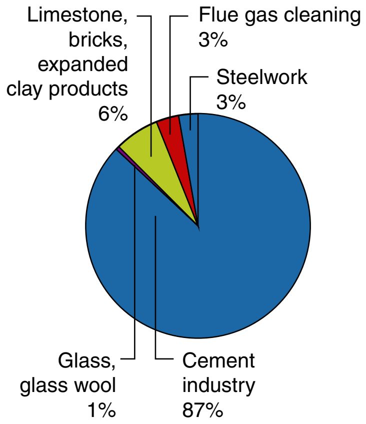


Figure 10.2 GHG emissions in CO_2 equivalents for stationary combustion. Distribution according to sources ('2010') and time-series for 1990 to 2030 for main sources.

10.2 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 1,750 ktonnes CO_2 equivalents. The most significant source is cement production, which contributes with more than 80% of the process-related GHG emission. Most of the processes are assumed to be constant at the same level as in 2004. 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 dependant on cement production.



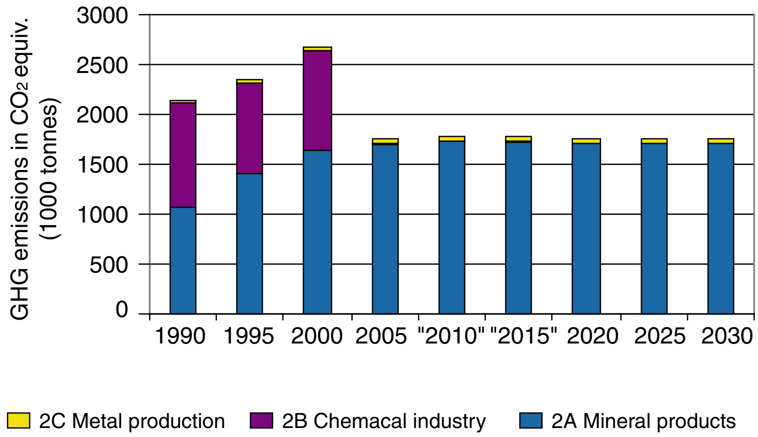
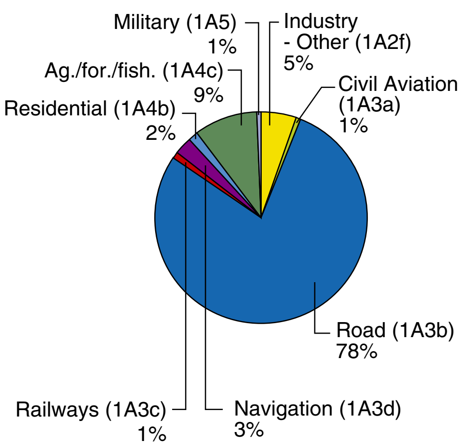


Figure 10.3 Total GHG emissions in CO_2 equivalents for industrial processes. Distribution according to main sectors ('2010') and time-series for 1990 to 2030.

10.3 Transport

Road transport is the main source of GHG emissions in '2010' and emissions from this sector are expected to increase by 59% from 1990 to 2030 due to growth in traffic. The emission shares for the remaining mobile sources are small compared with road transport, and from 1990 to 2030 the total share for these categories reduces from 32 to 20%. For agriculture/forestry/fisheries the emissions are expected to reduce by 27% during the same period due to a shift towards smaller numbers of agricultural tractors and harvesters but with larger engines. For industry (1A2f), the emissions increase by 4% from 1990-2030; for this sector there is an emission growth from 1990-2005 (due to increased activity), followed by a slight emission reduction from 2005-2030 due to machinery gradually becoming more fuel efficient. The latter explanation is also the reason for the small emission declines for Residential (gardening) (1A4b) and Navigation (1A3d) in the forecast period.



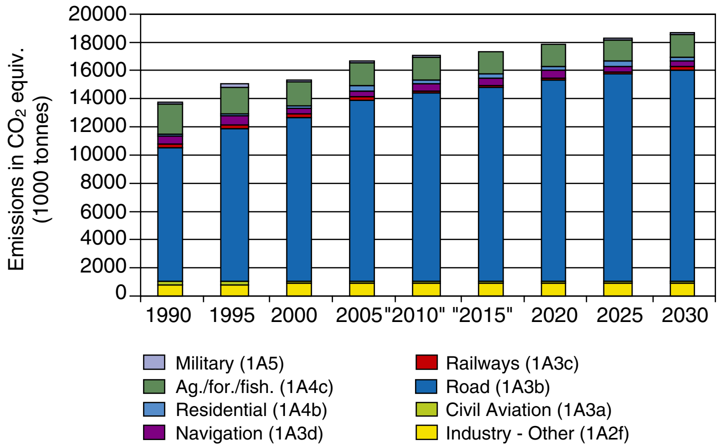


Figure 10.4 GHG emissions in CO_2 equivalents for mobile sources. Distribution according to sources ('2010') and time-series for 1990 to 2030 for main sources.

10.4 Fluorinated gases

Danish regulation concerning the powerful F-gas greenhouse gases 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 , and in '2010' are expected to contribute with 78% of the F-gas emission, Figure 10.5.

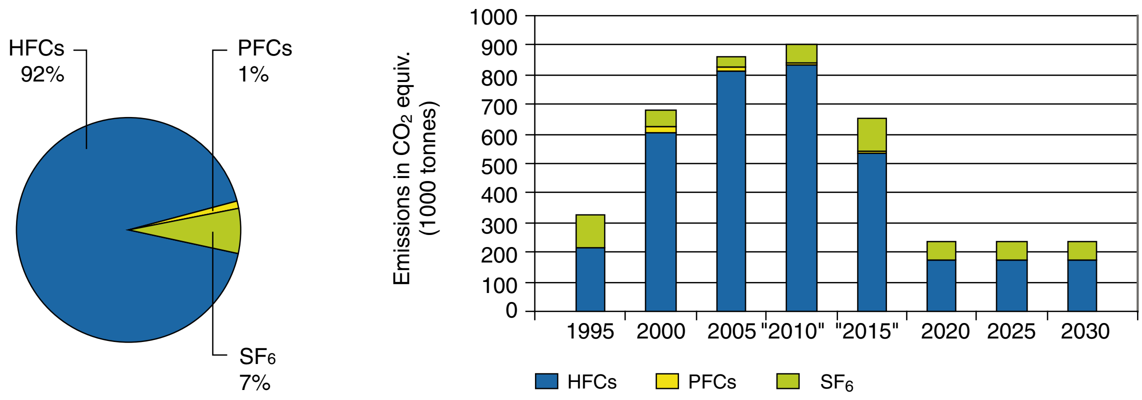


Figure 10.5 GHG emissions in CO_2 equivalents for F-gases. Distribution according to F-gas type (2010') and time-series for 1990 to 2030 for F-gas type

10.5 Agriculture

From 1990 to 2004, the emission of greenhouse gases in the agricultural sector has declined from 13,050 ktonnes CO_2 equivalents to 10,000 ktonnes CO_2 equivalents, which corresponds to a 23% reduction. This development continues, and the emission to 2030 is expected to fall further to 8,690 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 the stable and expansion of biogas production are taken into account in the projections but do not contribute to significant changes in the total greenhouse gas emission.

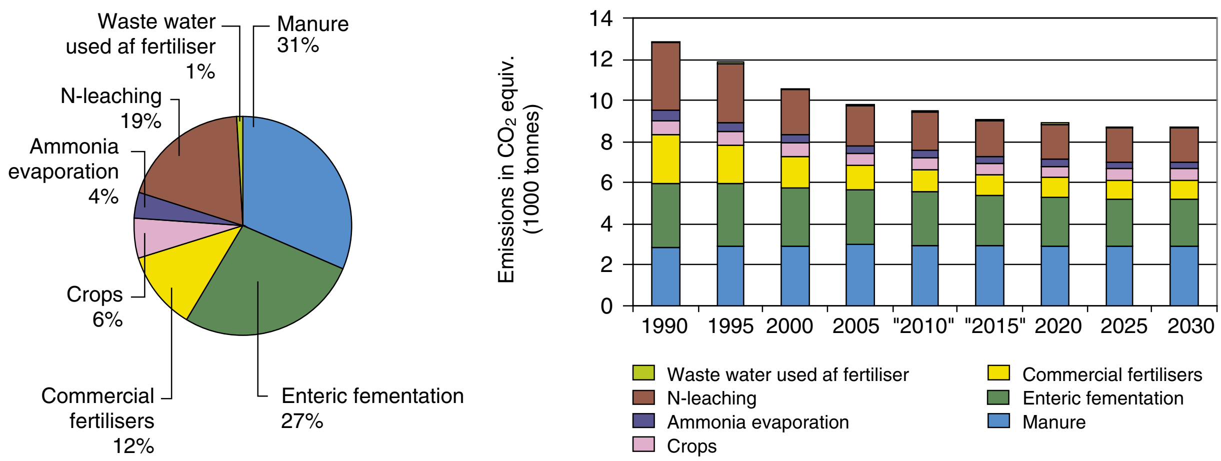


Figure 10.6 GHG emissions in CO_2 equivalents for agriculture sources. Distribution according to sources ('2010') and time-series for 1990 to 2030 for main sources.

10.6 Waste (Landfill sites and wastewater treatment)

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 78%, Figure 10.7.

The predicted emission of CH_4 from wastewater is only 18%. Some increase in the total amount of organic material in wastewater is foreseen, which would result in an increase in CH_4 emissions.

The emission of N_2O from wastewater is predicted to contribute to the total GHG emission for the sector with 4%. Due to the action plans for the aquatic environment, the N_2O emission is predicted to remain at an almost constant level.

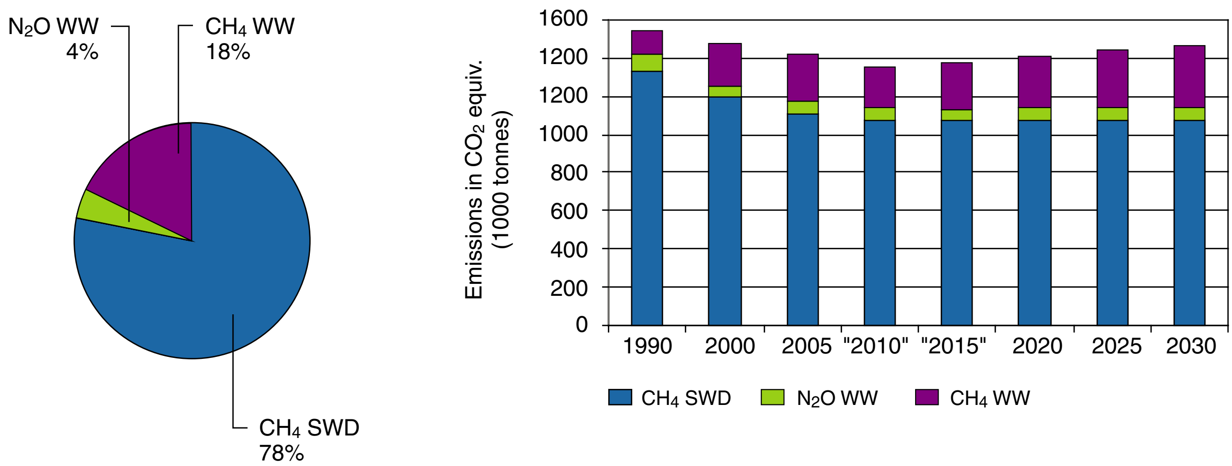


Figure 10.7 GHG emissions in CO_2 equivalents for Waste. Distribution according to source Wastewater (WW) and Solid Waste Disposal (SWD) and gas (‘2010’) and the time-series for 1990 to 2030.

Table 10.1 Historic and projected greenhouse gas (GHG) emissions in ktonnes CO_2 equivalents.

	Sektor	1990	1995	2000	2005	"2010"	"2015"	2020	2025	2030
1A1a	Public power	22899	28755	21427	13831	20970	19333	15637	13513	12030
1A1a	Gas turbines	110	590	1397	922	282	577	876	639	692
1A1a	District heating plants	1852	854	286	1624	1779	1737	1455	2043	1884
1A1b	Petroleum refining plants	908	1387	999	1018	1018	1018	1018	1018	1018
1A1c	Coal mining, oil / gas extraction, pipeline c	546	744	1467	1653	2499	4026	4856	4088	4088
1A2	Combustion in manufacturing industry	4639	5188	5146	4762	4886	4975	5023	5052	5059
1A2f	Industry - Other (mobile)	853	860	892	925	917	914	895	887	884
1A3a	Civil Aviation	246	202	157	130	136	144	155	165	176
1A3b	Road	9418	10798	11591	12856	13320	13721	14279	14641	14961
1A3c	Railways	300	306	230	204	204	204	204	204	204
1A3d	Navigation	566	667	472	477	437	426	426	426	426
1A4a	Commercial and institutional plants (t)	1419	1139	940	948	887	845	836	828	816
1A4b	Residential plants	5066	5132	4145	4037	3365	2962	2744	2618	2620
1A4b	Residential (mobile)	142	156	174	305	298	294	294	294	294
1A4c	Plants in agriculture, forestry and aquaculture	620	730	779	764	798	819	810	802	806
1A4c	Ag./for./fish. (mobile)	2112	1792	1711	1645	1612	1569	1553	1558	1549
1A5	Military (mobile)	120	256	112	124	124	125	125	125	125
1B2a	Fugitive emissions from oil	32	48	73	78	46	32	30	25	25
1B2b	Fugitive emissions from gas	6	12	5	4	4	3	2	2	2
1B2c	Fugitive emissions from flaring	267	369	600	459	626	654	654	475	475
2A	Mineral Products	1072	1407	1640	1703	1732	1727	1712	1709	1704
2B	Chemical Industry	1044	905	1004	3	3	3	3	3	3
2C	Metal Production	28	39	41	45	45	45	45	45	45
2F	Consumption of Halocarbons and SF6	44	326	682	864	900	655	235	235	235
3	Solvents (2004)	137	123	120	113	113	113	113	113	113
4A	Enteric Fermentation	3259	3169	2862	2681	2582	2441	2354	2275	2275
4B	Manure Management	1437	1509	1556	1552	1544	1522	1518	1513	1513
4D	Agricultural Soils	8352	7305	6193	5556	5317	5114	4999	4900	4900
6A1	Managed Waste Disposal on Land	1334	1286	1192	1109	1078	1072	1074	1077	1075
6B	Wastewater Handling	213	262	283	314	279	302	331	361	391
	Total without LULUCF	69042	76314	68174	60705	67800	67371	64257	61634	60386
1A3a	Civil Aviation, international	3149	5162	4365	2279	2361	2485	2701	2881	3072
1A3d	Navigation, international	1755	1888	2376	3201	3201	3201	3201	3201	3201

Table 10.2 Historic and projected CO_2 emissions in ktonnes CO_2 .

CO_2 emissions and projections (Gg)		KP Base Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
Denmark's Total Emissions excluding net CO2 and N2O from LULUCF		**52712**	**52712**	**60450**	**53070**	**54669**	**54262**	**59454**	**53941**	**47110**	**57990**	**57154**	**57744**	**56331**	**51991**	**53396**	**53895**	**54672**	**54853**	**52210**	**49825**	**48528**
1. Energy		**51474**	**51474**	**58880**	**51265**	**52847**	**52457**	**57772**	**52094**	**45246**	**56089**	**55252**	**55840**	**54432**	**50106**	**51509**	**52005**	**52778**	**52965**	**50336**	**47955**	**46663**
A Fuel Combustion Activities (Sectoral Approach)		**51211**	**51211**	**58515**	**50671**	**52213**	**51921**	**57222**	**51485**	**44789**	**55573**	**54692**	**55281**	**53858**	**49441**	**50845**	**51355**	**52156**	**52314**	**49686**	**47483**	**46191**
1 Energy Industries		**26173**	**26173**	**31934**	**25115**	**26400**	**26553**	**31402**	**25388**	**18561**	**29392**	**28578**	**29204**	**27821**	**23476**	**24887**	**25425**	**26162**	**26328**	**23383**	**20957**	**19372**
a Public Electricity and Heat Production		24736	24736	29828	22678	23972	24060	28869	22832	15923	26493	25584	26158	24727	20240	21041	21276	22688	21347	17581	15914	14329
b Petroleum Refining		897	897	1371	988	1009	971	1013	988	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006
c Manufacture of Solid Fuels and Other Energy Industries		540	540	735	1449	1419	1522	1520	1567	1632	1893	1988	2040	2087	2230	2840	3143	2468	3976	4796	4037	4037
2 Manufacturing Industries and Construction		**5423**	**5423**	**5974**	**5946**	**6018**	**5700**	**5698**	**5841**	**5585**	**5535**	**5554**	**5595**	**5656**	**5728**	**5753**	**5767**	**5700**	**5784**	**5813**	**5834**	**5839**
a Iron and Steel		326	326	282	330	342	408	408	401	401	401	401	401	401	401	401	401	401	401	401	401	401
b Non-Ferrous Metals		12	12	17	14	16	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
c Chemicals		379	379	437	476	509	458	458	461	461	461	461	461	461	461	461	461	461	461	461	461	461
d Pulp, Paper and Print		366	366	222	236	250	224	224	220	220	220	220	220	220	220	220	220	220	220	220	220	220
e Food Processing, Beverages and Tobacco		1679	1679	1888	1718	1712	1574	1575	1606	1606	1606	1606	1606	1606	1606	1606	1606	1606	1606	1606	1606	1606
f Other (please specify: ...)	... (1), (2)	2662	2662	3128	3174	3189	3023	3019	3139	2884	2833	2852	2893	2954	3027	3052	3065	2998	3083	3111	3133	3137
3 Transport		**10336**	**10336**	**11639**	**12004**	**11992**	**12170**	**12605**	**12859**	**13136**	**13358**	**13461**	**13516**	**13516**	**13456**	**13533**	**13618**	**13528**	**13911**	**14457**	**14805**	**15118**
a Civil Aviation		243	243	199	154	161	140	137	128	128	130	131	133	133	133	133	135	133	141	152	162	172
b Road Transportation		9241	9241	10483	11159	11163	11279	11722	12024	12338	12559	12668	12732	12745	12702	12779	12863	12764	13150	13685	14023	14327
c Railways		297	297	303	228	211	210	218	216	202	202	202	202	202	202	202	202	202	202	202	202	202
d Navigation		555	555	654	463	456	541	527	490	469	468	460	449	436	420	419	419	428	418	418	418	418
4 Other Sectors		**9159**	**9159**	**8716**	**7496**	**7707**	**7409**	**7426**	**7159**	**7385**	**7167**	**6978**	**6844**	**6743**	**6659**	**6549**	**6424**	**6644**	**6168**	**5911**	**5765**	**5740**
a Commercial/Institutional		1403	1403	1116	913	884	895	969	956	915	905	892	879	868	859	845	830	856	815	806	798	787
b Residential		5084	5084	5141	4173	4403	4179	4176	4065	4141	3963	3782	3653	3551	3460	3370	3263	3459	3047	2821	2687	2679
c Agriculture/Forestry/Fisheries		2673	2673	2459	2410	2420	2336	2281	2138	2328	2298	2304	2312	2324	2340	2335	2331	2328	2306	2283	2280	2274
5 Other (please specify: ...)	... (3)	**119**	**119**	**252**	**111**	**97**	**89**	**92**	**239**	**122**	**122**	**122**	**122**	**122**	**122**	**122**	**122**	**122**	**122**	**122**	**122**	**122**
B Fugitive Emissions from Fuels		**263**	**263**	**365**	**594**	**633**	**535**	**550**	**608**	**456**	**516**	**560**	**560**	**574**	**665**	**664**	**650**	**622**	**650**	**650**	**472**	**472**
1 Solid Fuels	NA, NO	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2 Oil and Natural Gas		**263**	**263**	**365**	**594**	**633**	**535**	**550**	**608**	**456**	**516**	**560**	**560**	**574**	**665**	**664**	**650**	**622**	**650**	**650**	**472**	**472**
a Oil	NA																					
b Natural Gas	NA,NO																					
c Venting and Flaring		263	263	365	594	633	535	550	608	456	516	560	560	574	665	664	650	622	650	650	472	472
Flaring		263	263	365	594	633	535	550	608	456	516	560	560	574	665	664	650	622	650	650	472	472
2. Industrial Processes		**1101**	**1101**	**1446**	**1682**	**1708**	**1697**	**1572**	**1731**	**1751**	**1788**	**1788**	**1791**	**1786**	**1772**	**1774**	**1776**	**1780**	**1775**	**1760**	**1757**	**1752**
A Mineral Products		**1072**	**1072**	**1407**	**1640**	**1660**	**1696**	**1571**	**1728**	**1703**	**1740**	**1740**	**1743**	**1738**	**1724**	**1726**	**1728**	**1732**	**1727**	**1712**	**1709**	**1704**
1 Cement Production		882	882	1204	1406	1432	1452	1370	1539	1539	1539	1539	1539	1539	1539	1539	1539	1539	1539	1539	1539	1539
2 Lime Production		152	152	132	123	119	141	112	110	110	110	110	110	110	110	110	110	110	110	110	110	110
3 Limestone and Dolomite Use		18	18	55	94	92	85	74	64	39	75	76	78	74	60	62	64	68	62	48	44	39
5 Asphalt Roofing	(< 0.5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 Road Paving with Asphalt		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
7 Other (please specify: ...)	... (4)	17	17	14	16	16	16	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
B Chemical Industry		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
2 Nitric Acid Production																						
5 Other (please specify: ...)	... (5)	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3
C Metal Production		**28**	**28**	**39**	**41**	**47**	**0**	**0**	**0**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**
1 Iron and Steel Production	2002-4: NO	28	28	39	41	47	0	0	0	45	45	45	45	45	45	45	45	45	45	45	45	45
4 SF6 Used in Aluminium and Magnesium Foundries																						
SF_6 Used in Magnesium Foundries																						
D Other Production	NE																					
E Production of Halocarbons and Sulphur Hexafluoride																						
F Consumption of Halocarbons and Sulphur Hexafluoride																						
1 Refrigeration and Air Conditioning Equipment																						
2 Foam Blowing																						
3 Fire Extinguishers																						
4. Aerosols/ Metered Dose Inhalers																						
8. Electrical Equipment (SF_6)																						
9 Other (please specify: see below)																						
C_3F_8 (...)	... (6)																					
SF_6 (...)	... (7)																					
G Other (please specify)	NA																					
3. Solvent and Other Product Use		**137**	**137**	**123**	**120**	**113**	**106**	**107**	**113**	**113**	**113**	**113**	**113**	**113**	**113**	**113**	**113**	**113**	**113**	**113**	**113**	**113**
A Paint Application		24	24	20	20	18	17	19	21	21	21	21	21	21	21	21	21	21	21	21	21	21
B Degreasing and Dry Cleaning		46	46	38	37	34	30	28	27	27	27	27	27	27	27	27	27	27	27	27	27	27
C Chemical Products, Manufacture and Processing		3	3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
D Other (please specify:)	... (8)	64	64	64	60	59	56	58	63	63	63	63	63	63	63	63	63	63	63	63	63	63
1. Use of N2O for Anaesthesia																						
2. N2O from Fire Extinguishers																						
3. N2O from Aerosol Cans																						
4. Other Use of N2O																						
5. Other (as specified in table 3.A-D)		64	64	64	60	59	56	58	63	63	63	63	63	63	63	63	63	63	63	63	63	63

CO_2 emissions and projections (Gg)		KP Base Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
4. Agriculture																						
A Enteric Fermentation																						
1 Cattle																						
Option A: 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																						
10 Other (please specify)																						
B Manure Management																						
1 Cattle																						
Option A: 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																						
10 Other livestock (please specify): Fur farming																						
11 Anaerobic Lagoons																						
12 Liquid Systems																						
13 Solid Storage and Dry Lot																						
14 Other AWMS																						
C Rice Cultivation																						
D Agricultural Soils																						
1. Direct Soil Emissions																						
2. Pasture, Range and Paddock Manure																						
3. Indirect Emissions																						
4. Other (please specify: see below)																						
Industrial waste used as fertilizer																						
Use of sewage slugde as fertilizer																						
E Prescribed Burning of Savannas																						
F Field Burning of Agricultural Residues (1)																						
G Other (please specify)																						
6. Waste		**0**	**0**	**0**	**3**	**2**	**3**	**3**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A Solid Waste Disposal on Land																						
1 Managed Waste Disposal on Land	NE																					
B Wastewater Handling																						
2 Domestic and Commercial Wastewater																						
C Waste Incineration	IE																	**0**	**0**	**0**	**0**	**0**
D Other (please specify: ...)	… (9)	**0**	**0**	**0**	**3**	**2**	**3**	**3**	**2**	**0**	**0**	**0**						**0**	**0**	**0**	**0**	**0**
7. Other (please specify)	NA																					
Memo Items (not included above):																						
International Bunkers		**4823**	**4823**	**6928**	**6629**	**5990**	**5025**	**5272**	**4992**	**5392**	**5429**	**5462**	**5478**	**5481**	**5471**	**5455**	**5479**	**5473**	**5595**	**5810**	**5987**	**6176**
Aviation		1736	1736	1867	2350	2385	2059	2142	2447	2254	2290	2324	2340	2343	2333	2317	2341	2335	2457	2672	2849	3038
Marine		3087	3087	5061	4279	3605	2966	3130	2545	3138	3138	3138	3138	3138	3138	3138	3138	3138	3138	3138	3138	3138
Multilateral Operations	NO																					
CO2 Emissions from Biomass		4641	4641	5869	7090	7696	8199	9114	9647													
Corrections (not included above):																						
CO2 emissions related to Net Electricity Import	… (10)	**6288**	**6288**	-690	659	-375	-1608	-6869	-2240	1140	-6106	-5009	-6749	-5498	-1991	-3087	-3434	-4152	-4820	-2001	-2658	-2546
CO2 emissions related to Temperature	… (11)	1768	1768	253	1120	28	721	334	401	424												

Notes:

… (1): Boilers, gas turbines, stationary engines
… (2): Industry mobile sources and machinery
… (3): Military mobile combustion of fuels
… (4): Glass Production
… (5): Catalysts/Fertilizers, Pesticides and Sulphuric acid
… (6): PFC used as detergent
… (7): Window plate production, Research laboratories and Running shoes
… (8): Other Products, Manufacture and Processing such as vessels, vehicles, machinery, wood, food and graphic
… (9): Gasification of biogas
… (10): minus means Net Electricity Export
… (11): temperature deviation from a normal year based on degree days
NO: Not occurring / NE: Not estimated / NA: Not applicable / IE: Included elsewhere

Table 10.3 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	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
Denmark's Total Emissions excluding net CO2 and N2O from LULUCF		**5692**	**5692**	**6025**	**5880**	**6026**	**5985**	**5966**	**5765**	**5783**	**5770**	**5568**	**5515**	**5478**	**5513**	**5457**	**5334**	**5459**	**5265**	**5297**	**5157**	**5187**
1. Energy		**222**	**222**	**526**	**654**	**686**	**682**	**682**	**687**	**740**	**711**	**565**	**566**	**564**	**613**	**617**	**522**	**576**	**514**	**597**	**498**	**500**
A Fuel Combustion Activities (Sectoral Approach)		**182**	**182**	**464**	**574**	**606**	**599**	**598**	**585**	**658**	**633**	**488**	**494**	**494**	**579**	**582**	**486**	**527**	**479**	**565**	**471**	**473**
1 Energy Industries		**23**	**23**	**242**	**312**	**337**	**336**	**330**	**323**	**346**	**322**	**181**	**188**	**190**	**276**	**282**	**187**	**225**	**186**	**275**	**177**	**173**
a Public Electricity and Heat Production		22	22	240	310	336	335	329	321	344	320	179	186	188	274	279	185	222	182	271	174	170
b Petroleum Refining		1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
c Manufacture of Solid Fuels and Other Energy Industries		0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	3	3	3	3
2 Manufacturing Industries and Construction		**15**	**15**	**18**	**32**	**34**	**31**	**31**	**32**	**40**	**40**	**40**	**40**	**40**	**41**	**41**	**41**	**41**	**41**	**41**	**41**	**40**
a Iron and Steel		1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
b Non-Ferrous Metals		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c Chemicals		0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
d Pulp, Paper and Print		1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
e Food Processing, Beverages and Tobacco		3	3	4	13	15	13	13	14	14	14	14	14	14	14	14	14	14	14	14	14	14
f Other (please specify: ...)	... (1), (2)	10	10	12	15	15	13	13	14	22	22	22	22	23	23	23	24	23	23	23	23	23
3 Transport		**53**	**53**	**75**	**69**	**68**	**62**	**60**	**54**	**63**	**61**	**58**	**54**	**51**	**46**	**43**	**40**	**47**	**32**	**24**	**21**	**21**
a Civil Aviation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b Road Transportation		52	52	73	68	67	61	59	53	62	60	57	53	50	46	42	39	46	31	23	21	20
c Railways		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
d Navigation		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4 Other Sectors		**91**	**91**	**130**	**161**	**167**	**170**	**177**	**176**	**210**	**210**	**209**	**211**	**213**	**215**	**216**	**217**	**214**	**220**	**225**	**232**	**239**
a Commercial/Institutional		4	4	13	19	19	19	19	19	21	21	21	21	21	21	21	20	21	20	20	20	19
b Residential		68	68	89	95	104	103	112	112	140	141	140	141	144	146	147	148	145	152	158	165	173
c Agriculture/Forestry/Fisheries		20	20	28	47	44	47	45	45	48	48	48	48	48	49	49	49	48	48	47	47	47
5 Other (please specify: ...)	... (3)	**0,104**	**0,104**	**0,306**	**0,106**	**0,115**	**0,087**	**0,094**	**0,225**	**0,115**	**0,112**	**0,107**	**0,103**	**0,100**	**0,096**	**0,093**	**0,091**	**0,097**	**0,085**	**0,079**	**0,077**	**0,077**
B Fugitive Emissions from Fuels		**40**	**40**	**62**	**80**	**80**	**83**	**84**	**102**	**81**	**78**	**77**	**72**	**70**	**35**	**35**	**36**	**50**	**35**	**32**	**27**	**27**
1 Solid Fuels	NA, NO	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2 Oil and Natural Gas		**40**	**40**	**62**	**80**	**80**	**83**	**84**	**102**	**81**	**78**	**77**	**72**	**70**	**35**	**35**	**36**	**50**	**35**	**32**	**27**	**27**
a Oil	NA	32	32	48	73	72	76	78	93	78	75	73	68	66	31	31	32	46	32	30	25	25
b Natural Gas	NA,NO	6	6	12	5	6	4	4	7	4	4	4	4	4	4	3	3	4	3	2	2	2
c Venting and Flaring		2	2	2	2	2	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Flaring		2	2	2	2	2	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Industrial Processes		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A Mineral Products		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Cement Production																						
2 Lime Production																						
3 Limestone and Dolomite Use																						
5 Asphalt Roofing																						
6 Road Paving with Asphalt																						
7 Other (please specify: ...)	... (4), IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B Chemical Industry		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2 Nitric Acid Production																						
5 Other (please specify: ...)	... (5), NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C Metal Production		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Iron and Steel Production	2002-4: NA,NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 SF6 Used in Aluminium and Magnesium Foundries																						
SF_6 Used in Magnesium Foundries																						
D Other Production																						
E Production of Halocarbons and Sulphur Hexafluoride																						
F Consumption of Halocarbons and Sulphur Hexafluoride																						
1 Refrigeration and Air Conditioning Equipment																						
2 Foam Blowing																						
3 Fire Extinguishers																						
4. Aerosols/ Metered Dose Inhalers																						
8. Electrical Equipment (SF_6)																						
9 Other (please specify: see below)																						
C_3F_8 (...)	... (6)																					
SF_6 (...)	... (7)																					
G Other (please specify)	NA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**						**0**	**0**	**0**	**0**	**0**
3. Solvent and Other Product Use																						
A Paint Application																						
B Degreasing and Dry Cleaning																						
C Chemical Products, Manufacture and Processing																						
D Other (please specify:)	... (8)																					

CH_4 emissions and projections (Gg CO_2 equivalents)		KP Base Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
4. Agriculture		**4011**	**4011**	**4036**	**3816**	**3921**	**3861**	**3821**	**3740**	**3681**	**3719**	**3680**	**3640**	**3622**	**3612**	**3547**	**3516**	**3587**	**3438**	**3356**	**3282**	**3282**
A Enteric Fermentation		**3259**	**3259**	**3169**	**2862**	**2920**	**2844**	**2801**	**2711**	**2681**	**2706**	**2671**	**2636**	**2615**	**2589**	**2550**	**2521**	**2582**	**2441**	**2354**	**2275**	**2275**
1 Cattle		2950	2950	2823	2484	2525	2448	2400	2305													
Option A: Dairy Cattle		1844	1844	1792	1564	1562	1555	1554	1493													
Non-Dairy Cattle		1106	1106	1031	920	963	893	846	812													
2 Buffalo	NO																					
3 Sheep		33	33	29	29	33	27	30	29													
4 Goats		2	2	3	3	3	3	3	3													
5 Camels and Llamas	NO																					
6 Horses		60	60	64	67	68	69	69	69													
7 Mules and Asses	NO																					
8 Swine		213	213	250	278	291	297	299	304													
9 Poultry	NE																					
10 Other (please specify: Fur farming)	NE	0	0	0	0	0	0	0	0													
B Manure Management		**752**	**752**	**868**	**954**	**1000**	**1018**	**1020**	**1030**	**1000**	**1013**	**1009**	**1005**	**1007**	**1023**	**997**	**994**	**1005**	**997**	**1002**	**1007**	**1007**
1 Cattle		282	282	268	260	270	273	280	272													
Option A: Dairy Cattle		213	213	216	214	222	229	238	233													
Non-Dairy Cattle		69	69	52	45	48	44	42	39													
2 Buffalo	NO																					
3 Sheep		1	1	1	1	1	0	1	1													
4 Goats		0	0	0	0	0	0	0	0													
5 Camels and Llamas	NO																					
6 Horses		4	4	5	5	5	5	5	5													
7 Mules and Asses	NO																					
8 Swine		448	448	578	667	698	710	705	720													
9 Poultry		6	6	7	6	6	6	6	6													
10 Other livestock (please specify): Fur farming		9	9	9	16	20	22	23	26													
11 Anaerobic Lagoons																						
12 Liquid Systems																						
13 Solid Storage and Dry Lot																						
14 Other AWMS																						
C Rice Cultivation	NA, NO	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
D Agricultural Soils		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1. Direct Soil Emissions	NE																					
2. Pasture, Range and Paddock Manure																						
3. Indirect Emissions	NE																					
4. Other (please specify: see below)																						
Industrial waste used as fertilizer	NO																					
Use of sewage slugde as fertilizer	NO																					
E Prescribed Burning of Savannas	NA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**									0	0	0	0	0
F Field Burning of Agricultural Residues	NA, NO	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
G Other (please specify)	NA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**									**0**	**0**	**0**	**0**	**0**
6. Waste		**1460**	**1460**	**1463**	**1409**	**1419**	**1442**	**1463**	**1338**	**1362**	**1341**	**1323**	**1309**	**1292**	**1288**	**1292**	**1297**	**1296**	**1313**	**1344**	**1377**	**1405**
A Solid Waste Disposal on Land		**1334**	**1334**	**1286**	**1192**	**1188**	**1131**	**1163**	**1074**	**1109**	**1095**	**1086**	**1084**	**1080**	**1078**	**1076**	**1074**	**1078**	**1072**	**1074**	**1077**	**1075**
1 Managed Waste Disposal on Land		1334	1334	1286	1192	1188	1131	1163	1074	1109	1095	1086	1084	1080	1078	1076	1074	1078	1072	1074	1077	1075
B Wastewater Handling		**126**	**126**	**177**	**217**	**231**	**310**	**299**	**265**	**253**	**246**	**237**	**226**	**212**	**211**	**217**	**223**	**217**	**240**	**270**	**300**	**329**
2 Domestic and Commercial Wastewater		126	126	177	217	231	310	299	265	253	246	237	226	212	211	217	223	217	240	270	300	329
C Waste Incineration	IE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**						**0**	**0**	**0**	**0**	**0**
D Other (please specify: ...)	… (9)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0,002**	**0**	**0**	**0**						**0**	**0**	**0**	**0**	**0**
7. Other (please specify)	NA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Memo Items (not included above):																				0	0	0
International Bunkers		**2**	**2**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Aviation		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Marine		1	1	2	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
Multilateral Operations	NO																					
CO2 Emissions from Biomass																						
Corrections (not included above):																						
CO2 emissions related to Net Electricity Import	… (10)																					
CO2 emissions related to Temperature	… (11)																					

Notes:

… (1): Boilers, gas turbines, stationary engines
… (2): Industry mobile sources and machinery
… (3): Military mobile combustion of fuels
… (4): Glass Production
… (5): Catalysts/Fertilizers, Pesticides and Sulphuric acid
… (6): PFC used as detergent
… (7): Window plate production, Research laboratories and Running shoes
… (8): Other Products, Manufacture and Processing such as vessels, vehicles, machinery, wood, food and graphic
… (9): Gasification of biogas
… (10): minus means Net Electricity Export
… (11): temperature deviation from a normal year based on degree days
NO: Not occurring / NE: Not estimated / NA: Not applicable / IE: Included elsewhere

Table 10.4 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	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
Denmark's Total Emissions excluding net CO2 and N2O from LULUCF		**10593**	**10593**	**9514**	**8545**	**8297**	**7944**	**7898**	**7589**	**6949**	**6929**	**6889**	**6848**	**6802**	**6742**	**6773**	**6679**	**6769**	**6598**	**6516**	**6416**	**6436**
1. Energy		**425**	**425**	**578**	**681**	**699**	**715**	**743**	**745**	**780**	**831**	**835**	**846**	**849**	**840**	**857**	**866**	**852**	**898**	**940**	**950**	**969**
A Fuel Combustion Activities (Sectoral Approach)		**424**	**424**	**576**	**678**	**695**	**712**	**740**	**741**	**778**	**828**	**832**	**843**	**846**	**836**	**853**	**862**	**848**	**895**	**936**	**947**	**966**
1 Energy Industries		**119**	**119**	**154**	**150**	**158**	**162**	**171**	**154**	**141**	**172**	**165**	**166**	**163**	**151**	**160**	**163**	**161**	**177**	**185**	**168**	**167**
a Public Electricity and Heat Production		103	103	131	122	130	133	142	125	110	138	129	130	126	112	115	114	119	118	116	108	108
b Petroleum Refining		9	9	15	11	11	11	11	11	12	12	12	12	12	12	12	12	12	12	12	12	12
c Manufacture of Solid Fuels and Other Energy Industries		6	6	9	17	17	18	18	19	19	22	24	24	25	26	34	37	29	47	57	48	48
2 Manufacturing Industries and Construction		**54**	**54**	**56**	**59**	**59**	**56**	**56**	**58**	**61**	**61**	**61**	**61**	**62**	**62**	**63**	**63**	**62**	**63**	**64**	**64**	**64**
a Iron and Steel		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
b Non-Ferrous Metals		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c Chemicals		3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
d Pulp, Paper and Print		3	3	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
e Food Processing, Beverages and Tobacco		13	13	13	13	13	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
f Other (please specify: ...)	... (1), (2)	33	33	36	37	38	36	36	38	41	40	40	41	41	42	42	42	42	43	43	44	44
3 Transport		**141**	**141**	**260**	**376**	**381**	**400**	**416**	**434**	**469**	**489**	**502**	**512**	**518**	**519**	**526**	**532**	**521**	**551**	**583**	**610**	**628**
a Civil Aviation		3	3	3	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3
b Road Transportation		125	125	242	363	369	386	402	421	456	477	490	500	506	507	514	520	509	539	571	597	615
c Railways		3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
d Navigation		10	10	12	8	8	10	9	9	8	8	8	8	8	7	7	7	8	7	7	7	7
4 Other Sectors		**109**	**109**	**102**	**92**	**95**	**93**	**96**	**91**	**105**	**103**	**102**	**102**	**102**	**102**	**102**	**101**	**102**	**101**	**101**	**103**	**104**
a Commercial/Institutional		12	12	10	8	7	7	9	8	11	11	11	11	11	10	10	10	10	10	10	10	10
b Residential		57	57	58	51	55	53	54	53	60	60	58	58	58	58	58	58	58	58	58	60	62
c Agriculture/Forestry/Fisheries		40	40	35	34	34	33	32	30	33	33	33	33	33	33	33	33	33	33	33	33	33
5 Other (please specify: ...)	... (3)	**1**	**1**	**4**	**1**	**2**	**1**	**1**	**4**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**3**	**2**	**3**	**3**	**3**	**3**
B Fugitive Emissions from Fuels		**1**	**1**	**2**	**3**	**3**	**3**	**3**	**3**	**2**	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**3**	**4**	**4**	**3**	**3**
1 Solid Fuels	NA, NO	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2 Oil and Natural Gas		**1**	**1**	**2**	**3**	**3**	**3**	**3**	**3**	**2**	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**3**	**4**	**4**	**3**	**3**
a Oil	NA																					
b Natural Gas																						
c Venting and Flaring		1	1	2	3	3	3	3	3	2	3	3	3	3	4	4	4	3	4	4	3	3
Flaring		1	1	2	3	3	3	3	3	2	3	3	3	3	4	4	4	3	4	4	3	3
2. Industrial Processes		**1043**	**1043**	**904**	**1004**	**885**	**774**	**895**	**531**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A Mineral Products		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Cement Production																						
2 Lime Production																						
3 Limestone and Dolomite Use																						
5 Asphalt Roofing																						
6 Road Paving with Asphalt																						
7 Other (please specify: ...)	... (4), IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B Chemical Industry		**1043**	**1043**	**904**	**1004**	**885**	**774**	**895**	**531**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2 Nitric Acid Production		1043	1043	904	1004	885	774	895	531	0	0	0	0	0	0	0	0	0	0	0	0	0
5 Other (please specify: ...)	... (5), NA,NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C Metal Production		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Iron and Steel Production																						
4 SF6 Used in Aluminium and Magnesium Foundries																						
SF_6 Used in Magnesium Foundries																						
D Other Production																						
E Production of Halocarbons and Sulphur Hexafluoride																						
F Consumption of Halocarbons and Sulphur Hexafluoride																						
1 Refrigeration and Air Conditioning Equipment																						
2 Foam Blowing																						
3 Fire Extinguishers																						
4. Aerosols/ Metered Dose Inhalers																						
8. Electrical Equipment (SF_6)																						
9 Other (please specify: see below)																						
C_3F_8 (...)	... (6)																					
SF_6 (...)	... (7)																					
G Other (please specify)	NA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
3. Solvent and Other Product Use		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A Paint Application																						
B Degreasing and Dry Cleaning	NA	0	0	0	0	0	0	0	0									0	0	0	0	0
C Chemical Products, Manufacture and Processing																		0	0	0	0	0
D Other (please specify:)	... (8), NA	0	0	0	0	0	0	0	0									0	0	0	0	0

N_2O emissions and projections (Gg CO_2 equivalents)		KP Base Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
4. Agriculture		**9037**	**9037**	**7947**	**6795**	**6656**	**6397**	**6210**	**6260**	**6108**	**6038**	**5993**	**5941**	**5892**	**5841**	**5855**	**5753**	**5856**	**5639**	**5515**	**5406**	**5406**
A Enteric Fermentation																						
1 Cattle																						
Option A: 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																						
10 Other (please specify)																						
B Manure Management		**685**	**685**	**642**	**601**	**605**	**586**	**558**	**561**	**552**	**538**	**538**	**536**	**535**	**532**	**565**	**527**	**539**	**524**	**516**	**505**	**505**
1 Cattle																						
Option A: 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																						
10 Other livestock (please specify): Fur farming																						
11 Anaerobic Lagoons	NO																	0	0	0	0	0
12 Liquid Systems		96	96	84	81	81	81	78	78									0	0	0	0	0
13 Solid Storage and Dry Lot		589	589	558	521	524	505	481	484									0	0	0	0	0
14 Other AWMS	NO																	0	0	0	0	0
C Rice Cultivation																						
D Agricultural Soils		**8352**	**8352**	**7305**	**6193**	**6051**	**5811**	**5652**	**5699**	**5556**	**5500**	**5455**	**5405**	**5357**	**5309**	**5291**	**5225**	**5317**	**5114**	**4999**	**4900**	**4900**
1. Direct Soil Emissions		4225	4225	3616	3238	3147	3004	2929	2942	2874	2859	2845	2831	2816	2797	2789	2767	2800	2724	2679	2635	2635
2. Pasture, Range and Paddock Manure		312	312	324	307	312	300	291	288	291	279	275	267	263	258	255	252	259	243	234	227	227
3. Indirect Emissions		3787	3787	3311	2595	2526	2438	2362	2390	2321	2292	2265	2237	2209	2184	2177	2138	2189	2077	2017	1971	1971
4. Other (please specify: see below)		28	28	55	53	65	70	70	79	70	70	70	70	70	70	69	69	70	70	68	68	68
Industrial waste used as fertilizer		9	9	27	31	44	49	49	61									0	0	0	0	0
Use of sewage slugde as fertilizer		19	19	28	22	21	22	21	18									0	0	0	0	0
E Prescribed Burning of Savannas	NA																	0	0	0	0	0
F Field Burning of Agricultural Residues	NA, NO																	0	0	0	0	0
G Other (please specify)	NA																	0	0	0	0	0
6. Waste		**88**	**88**	**85**	**65**	**57**	**58**	**50**	**53**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**
A Solid Waste Disposal on Land																						
1 Managed Waste Disposal on Land																						
B Wastewater Handling		**88**	**88**	**85**	**65**	**57**	**58**	**50**	**53**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**	**61**
2 Domestic and Commercial Wastewater		88	88	85	65	57	58	50	53	61	61	61	61	61	61	61	61	61	61	61	61	61
C Waste Incineration	IE																	**0**	**0**	**0**	**0**	**0**
D Other (please specify: ...)	… (9)	**0,000**	**0,000**	**0,003**	**0,025**	**0,017**	**0,019**	**0,022**	**0,015**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
7. Other (please specify)	NA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Memo Items (not included above):																						
International Bunkers		**78**	**78**	**119**	**109**	**96**	**80**	**84**	**76**	**85**	**86**	**86**	**86**	**86**	**86**	**86**	**86**	**86**	**88**	**90**	**92**	**94**
Aviation		18	18	20	25	26	22	23	26	24	25	25	25	25	25	25	25	25	26	29	31	33
Marine		60	60	99	84	71	58	61	50	61	61	61	61	61	61	61	61	61	61	61	61	61
Multilateral Operations	NO																					
CO2 Emissions from Biomass																						
Corrections (not included above):																						
CO2 emissions related to Net Electricity Import	… (10)																					
CO2 emissions related to Temperature	… (11)																					

Notes:

… (1): Boilers, gas turbines, stationary engines
… (2): Industry mobile sources and machinery
… (3): Military mobile combustion of fuels
… (4): Glass Production
… (5): Catalysts/Fertilizers, Pesticides and Sulphuric acid
… (6): PFC used as detergent
… (7): Window plate production, Research laboratories and Running shoes
… (8): Other Products, Manufacture and Processing such as vessels, vehicles, machinery, wood, food and graphic
… (9): Gasification of biogas
… (10): minus means Net Electricity Export
… (11): temperature deviation from a normal year based on degree days
NO: Not occurring / NE: Not estimated / NA: Not applicable / IE: Included elsewhere

Table 10.5 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	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
Denmark's Total Emissions excluding net CO2 and N2O from LULUCF		**218**	**0**	**218**	**605**	**647**	**672**	**695**	**749**	**815**	**837**	**889**	**892**	**873**	**853**	**804**	**740**	**832**	**536**	**171**	**171**	**171**
1. Energy																						
A Fuel Combustion Activities (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																						
a Iron and Steel																						
b Non-Ferrous Metals																						
c Chemicals																						
d Pulp, Paper and Print																						
e Food Processing, Beverages and Tobacco																						
f Other (please specify: ...)	... (1), (2)																					
3 Transport																						
a Civil Aviation																						
b Road Transportation																						
c Railways																						
d Navigation																						
4 Other Sectors																						
a Commercial/Institutional																						
b Residential																						
c Agriculture/Forestry/Fisheries																						
5 Other (please specify: ...)	... (3)																					
B Fugitive Emissions from Fuels																						
1 Solid Fuels																						
2 Oil and Natural Gas																						
a Oil																						
b Natural Gas																						
c Venting and Flaring																						
Flaring																						
2. Industrial Processes		**218**	**0**	**218**	**605**	**647**	**672**	**695**	**749**	**815**	**837**	**889**	**892**	**873**	**853**	**804**	**740**	**832**	**536**	**171**	**171**	**171**
A Mineral Products																						
1 Cement Production																						
2 Lime Production																						
3 Limestone and Dolomite Use																						
5 Asphalt Roofing																						
6 Road Paving with Asphalt																						
7 Other (please specify: ...)	... (4)																					
B Chemical Industry		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2 Nitric Acid Production																						
5 Other (please specify: ...)	... (5)																					
C Metal Production		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Iron and Steel Production																						
4 SF6 Used in Aluminium and Magnesium Foundries																						
SF_6 Used in Magnesium Foundries																						
D Other Production	NE																					
E Production of Halocarbons and Sulphur Hexafluoride										**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
F Consumption of Halocarbons and Sulphur Hexafluoride		**218**	**0**	**218**	**605**	**647**	**672**	**695**	**749**	**815**	**837**	**889**	**892**	**873**	**853**	**804**	**740**	**832**	**536**	**171**	**171**	**171**
1 Refrigeration and Air Conditioning Equipment		35	0	35	420	449	502	557	596	668	734	786	790	778	766	727	675	747	510	171	171	171
2 Foam Blowing		183	0	183	168	186	160	129	144	144	103	103	102	95	87	77	66	85	26	0	0	0
3 Fire Extinguishers	NO																	0	0	0	0	0
4. Aerosols/ Metered Dose Inhalers		0	0	0	17	12	10	10	9	4	0	0	0	0	0	0	0	0	0	0	0	0
8. Electrical Equipment (SF_6)																						
9 Other (please specify: see below)																						
C_3F_8 (...)	... (6)																					
SF_6 (...)	... (7)																					
G Other (please specify)	NA																					
3. Solvent and Other Product Use																						
A Paint Application																						
B Degreasing and Dry Cleaning																						
C Chemical Products, Manufacture and Processing																						
D Other (please specify:)	... (8)																					

HFCs emissions and projections (Gg CO_2 equivalents)		KP Base Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
4. Agriculture																						
A Enteric Fermentation																						
1 Cattle																						
Option A: 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																						
10 Other (please specify)																						
B Manure Management																						
1 Cattle																						
Option A: 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																						
10 Other livestock (please specify): Fur farming																						
11 Anaerobic Lagoons																						
12 Liquid Systems																						
13 Solid Storage and Dry Lot																						
14 Other AWMS																						
C Rice Cultivation																						
D Agricultural Soils																						
1. Direct Soil Emissions																						
2. Pasture, Range and Paddock Manure																						
3. Indirect Emissions																						
4. Other (please specify: see below)																						
Industrial waste used as fertilizer																						
Use of sewage slugde as fertilizer																						
E Prescribed Burning of Savannas																						
F Field Burning of Agricultural Residues (1)																						
G Other (please specify)																						
6. Waste																						
A Solid Waste Disposal on Land																						
1 Managed Waste Disposal on Land																						
B Wastewater Handling																						
2 Domestic and Commercial Wastewater																						
C Waste Incineration																						
D Other (please specify: ...)	… (9)																					
7. Other (please specify)																						
Memo Items (not included above):																						
International Bunkers																						
Aviation																						
Marine																						
Multilateral Operations																						
CO2 Emissions from Biomass																						
Corrections (not included above):																						
CO2 emissions related to Net Electricity Import	… (10)																					
CO2 emissions related to Temperature	… (11)																					

Notes:

… (1): Boilers, gas turbines, stationary engines
… (2): Industry mobile sources and machinery
… (3): Military mobile combustion of fuels
… (4): Glass Production
… (5): Catalysts/Fertilizers, Pesticides and Sulphuric acid
… (6): PFC used as detergent
… (7): Window plate production, Research laboratories and Running shoes
… (8): Other Products, Manufacture and Processing such as vessels, vehicles, machinery, wood, food and graphic
… (9): Gasification of biogas
… (10): minus means Net Electricity Export
… (11): temperature deviation from a normal year based on degree days
NO: Not occurring / NE: Not estimated / NA: Not applicable / IE: Included elsewhere

Table 10.6 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	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
Denmark's Total Emissions excluding net CO2 and N2O from LULUCF		1	0	1	18	22	22	19	16	14	12	11	10	10	9	9	9	9	7	6	6	6
1. Energy																						
A Fuel Combustion Activities (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																						
a Iron and Steel																						
b Non-Ferrous Metals																						
c Chemicals																						
d Pulp, Paper and Print																						
e Food Processing, Beverages and Tobacco																						
f Other (please specify: ...)	... (1), (2)																					
3 Transport																						
a Civil Aviation																						
b Road Transportation																						
c Railways																						
d Navigation																						
4 Other Sectors																						
a Commercial/Institutional																						
b Residential																						
c Agriculture/Forestry/Fisheries																						
5 Other (please specify: ...)	... (3)																					
B Fugitive Emissions from Fuels																						
1 Solid Fuels																						
2 Oil and Natural Gas																						
a Oil																						
b Natural Gas																						
c Venting and Flaring																						
Flaring																						
2. Industrial Processes		1	0	1	18	22	22	19	16	14	12	11	10	10	9	9	9	9	7	6	6	6
A Mineral Products																						
1 Cement Production																						
2 Lime Production																						
3 Limestone and Dolomite Use																						
5 Asphalt Roofing																						
6 Road Paving with Asphalt																						
7 Other (please specify: ...)	... (4)																					
B Chemical Industry		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 Nitric Acid Production																						
5 Other (please specify: ...)	... (5), NA																					
C Metal Production		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 Iron and Steel Production																						
4 SF6 Used in Aluminium and Magnesium Foundries																						
SF_6 Used in Magnesium Foundries																						
D Other Production																						
E Production of Halocarbons and Sulphur Hexafluoride		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F Consumption of Halocarbons and Sulphur Hexafluoride		1	0	1	18	22	22	19	16	14	12	11	10	10	9	9	9	9	7	6	6	6
1 Refrigeration and Air Conditioning Equipment		1	0	1	16	18	19	18	16	14	12	11	10	10	9	9	9	9	7	6	6	6
2 Foam Blowing	NA																					
3 Fire Extinguishers	NO																					
4. Aerosols/ Metered Dose Inhalers	NA																					
8. Electrical Equipment (SF_6)	NA																					
9 Other (please specify: see below)		0	0	0	2	4	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C_3F_8 (...)	... (6)	0	0	0	2	4	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF_6 (...)	... (7)																					
G Other (please specify)	NA																					
3. Solvent and Other Product Use																						
A Paint Application																						
B Degreasing and Dry Cleaning																						
C Chemical Products, Manufacture and Processing																						
D Other (please specify:)	... (8)																					

PFCs emissions and projections (Gg CO_2 equivalents)		KP Base Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
4. Agriculture																						
A Enteric Fermentation																						
1 Cattle																						
Option A: 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																						
10 Other (please specify)																						
B Manure Management																						
1 Cattle																						
Option A: 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																						
10 Other livestock (please specify): Fur farming																						
11 Anaerobic Lagoons																						
12 Liquid Systems																						
13 Solid Storage and Dry Lot																						
14 Other AWMS																						
C Rice Cultivation																						
D Agricultural Soils																						
1. Direct Soil Emissions																						
2. Pasture, Range and Paddock Manure																						
3. Indirect Emissions																						
4. Other (please specify: see below)																						
Industrial waste used as fertilizer																						
Use of sewage slugde as fertilizer																						
E Prescribed Burning of Savannas																						
F Field Burning of Agricultural Residues (1)																						
G Other (please specify)																						
6. Waste																						
A Solid Waste Disposal on Land																						
1 Managed Waste Disposal on Land																						
B Wastewater Handling																						
2 Domestic and Commercial Wastewater																						
C Waste Incineration																						
D Other (please specify: ...)	… (9)																					
7. Other (please specify)																						
Memo Items (not included above):																						
International Bunkers																						
Aviation																						
Marine																						
Multilateral Operations																						
CO2 Emissions from Biomass																						
Corrections (not included above):																						
CO2 emissions related to Net Electricity Import	… (10)																					
CO2 emissions related to Temperature	… (11)																					

Notes:
… (1): Boilers, gas turbines, stationary engines
… (2): Industry mobile sources and machinery
… (3): Military mobile combustion of fuels
… (4): Glass Production
… (5): Catalysts/Fertilizers, Pesticides and Sulphuric acid
… (6): PFC used as detergent
… (7): Window plate production, Research laboratories and Running shoes
… (8): Other Products, Manufacture and Processing such as vessels, vehicles, machinery, wood, food and graphic
… (9): Gasification of biogas
… (10): minus means Net Electricity Export
… (11): temperature deviation from a normal year based on degree days
NO: Not occurring / NE: Not estimated / NA: Not applicable / IE: Included elsewhere

Table 10.7 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	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
Denmark's Total Emissions excluding net CO2 and N2O from LULUCF		**107**	**44**	**107**	**59**	**30**	**25**	**31**	**33**	**35**	**36**	**36**	**36**	**36**	**37**	**69**	**115**	**59**	**112**	**59**	**59**	**59**
1. Energy																						
A Fuel Combustion Activities (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																						
a Iron and Steel																						
b Non-Ferrous Metals																						
c Chemicals																						
d Pulp, Paper and Print																						
e Food Processing, Beverages and Tobacco																						
f Other (please specify: ...)	... (1), (2)																					
3 Transport																						
a Civil Aviation																						
b Road Transportation																						
c Railways																						
d Navigation																						
4 Other Sectors																						
a Commercial/Institutional																						
b Residential																						
c Agriculture/Forestry/Fisheries																						
5 Other (please specify: ...)	... (3)																					
B Fugitive Emissions from Fuels																						
1 Solid Fuels																						
2 Oil and Natural Gas																						
a Oil																						
b Natural Gas																						
c Venting and Flaring																						
Flaring																						
2. Industrial Processes		**107**	**44**	**107**	**59**	**30**	**25**	**31**	**33**	**35**	**36**	**36**	**36**	**36**	**37**	**69**	**115**	**59**	**112**	**59**	**59**	**59**
A Mineral Products																						
1 Cement Production																						
2 Lime Production																						
3 Limestone and Dolomite Use																						
5 Asphalt Roofing																						
6 Road Paving with Asphalt																						
7 Other (please specify: ...)	... (4)																					
B Chemical Industry		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2 Nitric Acid Production																						
5 Other (please specify: ...)	... (5)																	0	0	0	0	0
C Metal Production		**36**	**31**	**36**	**21**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Iron and Steel Production																						
4 SF_6 Used in Aluminium and Magnesium Foundries		36	31	36	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF_6 Used in Magnesium Foundries	2001- :NO	36	31	36	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D Other Production																						
E Production of Halocarbons and Sulphur Hexafluoride	NA, NO																					
F Consumption of Halocarbons and Sulphur Hexafluoride		**71**	**13**	**71**	**38**	**30**	**25**	**31**	**33**	**35**	**36**	**36**	**36**	**36**	**37**	**69**	**115**	**59**	**112**	**59**	**59**	**59**
1 Refrigeration and Air Conditioning Equipment	NA																					
2 Foam Blowing	NA																					
3 Fire Extinguishers	NO																					
4. Aerosols/ Metered Dose Inhalers	NA																					
8. Electrical Equipment (SF_6)		4	1	4	11	13	9	10	10	12	12	12	13	13	13	14	14	13	15	16	16	16
9 Other (please specify: see below)		68	12	68	27	18	16	22	23	23	24	24	23	23	23	55	101	45	97	43	43	43
C_3F_8 (...)	... (6)																					
SF_6 (...)	... (7)	68	12	68	27	18	16	22	23	23	24	24	23	23	23	55	101	45	97	43	43	43
G Other (please specify)	NA																	**0**	**0**	**0**	**0**	**0**
3. Solvent and Other Product Use																						
A Paint Application																						
B Degreasing and Dry Cleaning																						
C Chemical Products, Manufacture and Processing																						
D Other (please specify:)	... (8)																					

SF_6 emissions and projections (Gg CO_2 equivalents)		KP Base Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
4. Agriculture																						
A Enteric Fermentation																						
1 Cattle																						
Option A: 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																						
10 Other (please specify)																						
B Manure Management																						
1 Cattle																						
Option A: 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																						
10 Other livestock (please specify): Fur farming																						
11 Anaerobic Lagoons																						
12 Liquid Systems																						
13 Solid Storage and Dry Lot																						
14 Other AWMS																						
C Rice Cultivation																						
D Agricultural Soils																						
1. Direct Soil Emissions																						
2. Pasture, Range and Paddock Manure																						
3. Indirect Emissions																						
4. Other (please specify: see below)																						
Industrial waste used as fertilizer																						
Use of sewage slugde as fertilizer																						
E Prescribed Burning of Savannas																						
F Field Burning of Agricultural Residues (1)																						
G Other (please specify)																						
6. Waste																						
A Solid Waste Disposal on Land																						
1 Managed Waste Disposal on Land																						
B Wastewater Handling																						
2 Domestic and Commercial Wastewater																						
C Waste Incineration																						
D Other (please specify: ...)	… (9)																					
7. Other (please specify)																						
Memo Items (not included above):																						
International Bunkers																						
Aviation																						
Marine																						
Multilateral Operations																						
CO2 Emissions from Biomass																						
Corrections (not included above):																						
CO2 emissions related to Net Electricity Import	… (10)																					
CO2 emissions related to Temperature	… (11)																					

Notes:

… (1): Boilers, gas turbines, stationary engines
… (2): Industry mobile sources and machinery
… (3): Military mobile combustion of fuels
… (4): Glass Production
… (5): Catalysts/Fertilizers, Pesticides and Sulphuric acid
… (6): PFC used as detergent
… (7): Window plate production, Research laboratories and Running shoes
… (8): Other Products, Manufacture and Processing such as vessels, vehicles, machinery, wood, food and graphic
… (9): Gasification of biogas
… (10): minus means Net Electricity Export
… (11): temperature deviation from a normal year based on degree days
NO: Not occurring / NE: Not estimated / NA: Not applicable / IE: Included elsewhere

Table 10.8 Historic and projected greenhouse gas (GHG) emissions in ktonnes CO_2 equivalents.

GHG emissions and projections (Gg CO_2 equivalents)		KP Base Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
Denmark's Total Emissions excluding net CO2 and N2O from LULUCF		69323,336	69042	76314	68177	69693	68910	74064	68092	60705	71575	70547	71046	69531	65146	66508	66772	67800	67371	64257	61634	60386
1. Energy		52121	52121	59984	52601	54231	53853	59197	53525	46765	57630	56652	57252	55844	51559	52982	53393	54206	54377	51873	49403	48132
A Fuel Combustion Activities (Sectoral Approach)		51817	51817	59555	51924	53514	53232	58560	52812	46225	57033	56012	56618	55198	50856	52280	52703	53531	53688	51187	48901	47631
1 Energy Industries		26315	26315	32330	25576	26895	27051	31902	25865	19048	29886	28923	29558	28173	23903	25329	25775	26548	26691	23843	21302	19713
a Public Electricity and Heat Production		24861	24861	30199	23110	24438	24528	29339	23278	16377	26951	25892	26474	25041	20627	21435	21574	23030	21647	17968	16195	14606
b Petroleum Refining		908	908	1387	999	1020	982	1024	999	1018	1018	1018	1018	1018	1018	1018	1018	1018	1018	1018	1018	1018
c Manufacture of Solid Fuels and Other Energy Industries		546	546	744	1467	1436	1541	1539	1588	1653	1917	2013	2066	2114	2258	2876	3183	2499	4026	4856	4088	4088
2 Manufacturing Industries and Construction		5493	5493	6048	6037	6111	5787	5785	5931	5687	5635	5654	5697	5758	5832	5857	5871	5803	5889	5918	5939	5943
a Iron and Steel		329	329	284	335	347	413	413	407	407	407	407	407	407	407	407	407	407	407	407	407	407
b Non-Ferrous Metals		12	12	17	14	16	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
c Chemicals		382	382	441	481	514	462	462	465	465	465	465	465	465	465	465	465	465	465	465	465	465
d Pulp, Paper and Print		370	370	223	238	252	226	226	222	222	222	222	222	222	222	222	222	222	222	222	222	222
e Food Processing, Beverages and Tobacco		1695	1695	1905	1744	1740	1599	1601	1632	1632	1632	1632	1632	1632	1632	1632	1632	1632	1632	1632	1632	1632
f Other (please specify: ...)	… (1), (2)	2706	2706	3177	3227	3242	3073	3069	3191	2947	2895	2914	2957	3018	3092	3117	3131	3063	3149	3178	3199	3203
3 Transport		10529	10529	11973	12449	12441	12632	13081	13346	13667	13908	14021	14082	14085	14022	14102	14190	14096	14494	15064	15436	15766
a Civil Aviation		246	246	202	157	164	142	139	131	130	132	134	135	136	136	136	137	136	144	155	165	176
b Road Transportation		9418	9418	10798	11591	11599	11726	12184	12498	12856	13095	13215	13286	13301	13255	13335	13422	13320	13721	14279	14641	14961
c Railways		300	300	306	230	213	212	220	218	204	204	204	204	204	204	204	204	204	204	204	204	204
d Navigation		566	566	667	472	464	551	537	500	477	477	468	458	444	428	427	427	437	426	426	426	426
4 Other Sectors		9359	9359	8948	7749	7969	7672	7698	7427	7699	7480	7289	7156	7057	6976	6867	6742	6960	6489	6237	6100	6084
a Commercial/Institutional		1419	1419	1139	940	910	921	997	982	948	937	924	910	900	890	876	860	887	845	836	828	816
b Residential		5208	5208	5288	4319	4561	4335	4343	4231	4342	4164	3981	3853	3752	3664	3575	3469	3663	3257	3038	2912	2913
c Agriculture/Forestry/Fisheries		2732	2732	2521	2490	2498	2416	2358	2213	2410	2379	2385	2393	2405	2422	2417	2413	2410	2388	2364	2361	2355
5 Other (please specify: ...)	… (3)	120	120	256	112	99	90	94	243	124	124	124	124	124	124	124	124	124	125	125	125	125
B Fugitive Emissions from Fuels		304	304	429	677	717	621	637	713	540	597	640	634	647	703	702	690	675	689	686	501	501
1 Solid Fuels	NA, NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 Oil and Natural Gas		304	304	429	677	717	621	637	713	540	597	640	634	647	703	702	690	675	689	686	501	501
a Oil		32	32	48	73	72	76	78	93	78	75	73	68	66	31	31	32	46	32	30	25	25
b Natural Gas		6	6	12	5	6	4	4	7	4	4	4	4	4	4	3	3	4	3	2	2	2
c Venting and Flaring		267	267	369	600	639	541	555	614	459	519	564	563	577	668	667	654	626	654	654	475	475
Flaring		267	267	369	600	639	541	555	614	459	519	564	563	577	668	667	654	626	654	654	475	475
2. Industrial Processes		2470	2189	2676	3367	3293	3190	3213	3060	2615	2673	2724	2729	2706	2671	2656	2640	2680	2430	1995	1992	1987
A Mineral Products		1072	1072	1407	1640	1660	1696	1571	1728	1703	1740	1740	1743	1738	1724	1726	1728	1732	1727	1712	1709	1704
1 Cement Production		882	882	1204	1406	1432	1452	1370	1539	1539	1539	1539	1539	1539	1539	1539	1539	1539	1539	1539	1539	1539
2 Lime Production		152	152	132	123	119	141	112	110	110	110	110	110	110	110	110	110	110	110	110	110	110
3 Limestone and Dolomite Use		18	18	55	94	92	85	74	64	39	75	76	78	74	60	62	64	68	62	48	44	39
5 Asphalt Roofing	(< 0.5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 Road Paving with Asphalt		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
7 Other (please specify: ...)	… (4)	17	17	14	16	16	16	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
B Chemical Industry		1044	1044	905	1004	886	775	896	534	3	3	3	3	3	3	3	3	3	3	3	3	3
2 Nitric Acid Production		1043	1043	904	1004	885	774	895	531	0	0	0	0	0	0	0	0	0	0	0	0	0
5 Other (please specify: ...)	… (5)	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3
C Metal Production		64	60	74	62	47	0	0	0	45	45	45	45	45	45	45	45	45	45	45	45	45
1 Iron and Steel Production	2002-4: NO	28	28	39	41	47	0	0	0	45	45	45	45	45	45	45	45	45	45	45	45	45
4 SF_6 Used in Aluminium and Magnesium Foundries		36	31	36	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF_6 Used in Magnesium Foundries		36	31	36	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D Other Production	NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E Production of Halocarbons and Sulphur Hexafluoride	NA, NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F Consumption of Halocarbons and Sulphur Hexafluoride		290	13	290	660	700	719	746	798	864	885	936	938	919	899	882	864	900	655	235	235	235
1 Refrigeration and Air Conditioning Equipment		36	0	36	436	468	521	575	612	682	746	797	800	788	775	736	683	756	517	176	176	176
2 Foam Blowing		183	0	183	168	186	160	129	144	144	103	103	102	95	87	77	66	85	26	0	0	0
3 Fire Extinguishers		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4. Aerosols/ Metered Dose Inhalers		0	0	0	17	12	10	10	9	4	0	0	0	0	0	0	0	0	0	0	0	0
8. Electrical Equipment (SF_6)		4	1	4	11	13	9	10	10	12	12	12	13	13	13	14	14	13	15	16	16	16
9 Other (please specify: see below)		68	12	68	29	21	20	23	23	23	24	24	23	23	23	55	101	45	97	43	43	43
C_3F_8 (...)	… (6)	0	0	0	2	4	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF_6 (...)	… (7)	68	12	68	27	18	16	22	23	23	24	24	23	23	23	55	101	45	97	43	43	43
G Other (please specify)	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Solvent and Other Product Use		137	137	123	120	113	106	107	113	113	113	113	113	113	113	113	113	113	113	113	113	113
A Paint Application		24	24	20	20	18	17	19	21	21	21	21	21	21	21	21	21	21	21	21	21	21
B Degreasing and Dry Cleaning		46	46	38	37	34	30	28	27	27	27	27	27	27	27	27	27	27	27	27	27	27
C Chemical Products, Manufacture and Processing		3	3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
D Other (please specify:)	… (8)	64	64	64	60	59	56	58	63	63	63	63	63	63	63	63	63	63	63	63	63	63

GHG emissions and projections (Gg CO_2 equivalents)		KP Base Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
4. Agriculture		**13048**	**13048**	**11983**	**10611**	**10577**	**10258**	**10031**	**10000**	**9788**	**9756**	**9673**	**9581**	**9514**	**9453**	**9402**	**9268**	**9444**	**9077**	**8870**	**8688**	**8688**
A Enteric Fermentation		**3259**	**3259**	**3169**	**2862**	**2920**	**2844**	**2801**	**2711**	**2681**	**2706**	**2671**	**2636**	**2615**	**2589**	**2550**	**2521**	**2582**	**2441**	**2354**	**2275**	**2275**
1 Cattle		2950	2950	2823	2484	2525	2448	2400	2305													
Option A: Dairy Cattle		1844	1844	1792	1564	1562	1555	1554	1493													
Non-Dairy Cattle		1106	1106	1031	920	963	893	846	812													
2 Buffalo	NO	0	0	0	0	0	0	0	0													
3 Sheep		33	33	29	29	33	27	30	29													
4 Goats		2	2	3	3	3	3	3	3													
5 Camels and Llamas	NO	0	0	0	0	0	0	0	0													
6 Horses		60	60	64	67	68	69	69	69													
7 Mules and Asses	NO	0	0	0	0	0	0	0	0													
8 Swine		213	213	250	278	291	297	299	304													
9 Poultry	NE	0	0	0	0	0	0	0	0													
10 Other (please specify)	NE	0	0	0	0	0	0	0	0													
B Manure Management		**1437**	**1437**	**1509**	**1556**	**1605**	**1604**	**1578**	**1591**	**1552**	**1551**	**1547**	**1541**	**1542**	**1554**	**1561**	**1522**	**1544**	**1522**	**1518**	**1513**	**1513**
1 Cattle		282	282	268	260	270	273	280	272													
Option A: Dairy Cattle		213	213	216	214	222	229	238	233													
Non-Dairy Cattle		69	69	52	45	48	44	42	39													
2 Buffalo	NO	0	0	0	0	0	0	0	0													
3 Sheep		1	1	1	1	1	0	1	1													
4 Goats		0	0	0	0	0	0	0	0													
5 Camels and Llamas	NO	0	0	0	0	0	0	0	0													
6 Horses		4	4	5	5	5	5	5	5													
7 Mules and Asses	NO	0	0	0	0	0	0	0	0													
8 Swine		448	448	578	667	698	710	705	720													
9 Poultry		6	6	7	6	6	6	6	6													
10 Other livestock (please specify): Fur farming		9	9	9	16	20	22	23	26													
11 Anaerobic Lagoons	NO	0	0	0	0	0	0	0	0													
12 Liquid Systems		96	96	84	81	81	81	78	78													
13 Solid Storage and Dry Lot		589	589	558	521	524	505	481	484													
14 Other AWMS	NO	0	0	0	0	0	0	0	0													
C Rice Cultivation	NA, NO	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
D Agricultural Soils		**8352**	**8352**	**7305**	**6193**	**6051**	**5811**	**5652**	**5699**	**5556**	**5500**	**5455**	**5405**	**5357**	**5309**	**5291**	**5225**	**5317**	**5114**	**4999**	**4900**	**4900**
1. Direct Soil Emissions		4225	4225	3616	3238	3147	3004	2929	2942	2874	2859	2845	2831	2816	2797	2789	2767	2800	2724	2679	2635	2635
2. Pasture, Range and Paddock Manure		312	312	324	307	312	300	291	288	291	279	275	267	263	258	255	252	259	243	234	227	227
3. Indirect Emissions		3787	3787	3311	2595	2526	2438	2362	2390	2321	2292	2265	2237	2209	2184	2177	2138	2189	2077	2017	1971	1971
4. Other (please specify: see below)		28	28	55	53	65	70	70	79	70	70	70	70	70	70	69	69	70	70	68	68	68
Industrial waste used as fertilizer		9	9	27	31	44	49	49	61													
Use of sewage slugde as fertilizer		19	19	28	22	21	22	21	18													
E Prescribed Burning of Savannas	NA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
F Field Burning of Agricultural Residues (1)	NA, NO	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
G Other (please specify)	NA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
6. Waste		**1547**	**1547**	**1548**	**1478**	**1479**	**1502**	**1515**	**1394**	**1423**	**1402**	**1384**	**1370**	**1354**	**1349**	**1353**	**1358**	**1357**	**1374**	**1405**	**1438**	**1466**
A Solid Waste Disposal on Land		**1334**	**1334**	**1286**	**1192**	**1188**	**1131**	**1163**	**1074**	**1109**	**1095**	**1086**	**1084**	**1080**	**1078**	**1076**	**1074**	**1078**	**1072**	**1074**	**1077**	**1075**
1 Managed Waste Disposal on Land		1334	1334	1286	1192	1188	1131	1163	1074	1109	1095	1086	1084	1080	1078	1076	1074	1078	1072	1074	1077	1075
B Wastewater Handling		**213**	**213**	**262**	**283**	**289**	**369**	**349**	**318**	**314**	**307**	**298**	**287**	**273**	**272**	**278**	**284**	**279**	**302**	**331**	**361**	**391**
2 Domestic and Commercial Wastewater		213	213	262	283	289	369	349	318	314	307	298	287	273	272	278	284	279	302	331	361	391
C Waste Incineration	IE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
D Other (please specify: ...)	... (9)	**0**	**0**	**0**	**3**	**2**	**3**	**3**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
7. Other (please specify)	NA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Memo Items (not included above):																						
International Bunkers		**4904**	**4904**	**7050**	**6741**	**6088**	**5108**	**5359**	**5070**	**5480**	**5517**	**5551**	**5567**	**5570**	**5560**	**5544**	**5568**	**5562**	**5686**	**5902**	**6082**	**6273**
Aviation		1755	1755	1888	2376	2411	2083	2166	2475	2279	2316	2350	2366	2369	2359	2343	2367	2361	2485	2701	2881	3072
Marine		3149	3149	5162	4365	3677	3025	3193	2596	3201	3201	3201	3201	3201	3201	3201	3201	3201	3201	3201	3201	3201
Multilateral Operations	NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CO2 Emissions from Biomass		4641	4641	5869	7090	7696	8199	9114	9647	0	0	0	0	0	0	0	0	0	0	0	0	0
Corrections (not included above):																						
CO2 emissions related to Net Electricity Import	... (10)	6288	6288	-690	659	-375	-1608	-6869	-2240	1140	-6106	-5009	-6749	-5498	-1991	-3087	-3434	-4152	-4820	-2001	-2658	-2546
CO2 emissions related to Temperature	... (11)	1768	1768	253	1120	28	721	334	401	424	0	0	0	0	0	0	0	0	0	0	0	0

Notes:

... (1): Boilers, gas turbines, stationary engines
... (2): Industry mobile sources and machinery
... (3): Military mobile combustion of fuels
... (4): Glass Production
... (5): Catalysts/Fertilizers, Pesticides and Sulphuric acid
... (6): PFC used as detergent
... (7): Window plate production, Research laboratories and Running shoes
... (8): Other Products, Manufacture and Processing such as vessels, vehicles, machinery, wood, food and graphic
... (9): Gasification of biogas
... (10): minus means Net Electricity Export
... (11): temperature deviation from a normal year based on degree days
NO: Not occurring / NE: Not estimated / NA: Not applicable / IE: Included elsewhere

Table 10.9 Trends in greenhouse gas (GHG) emissions and distributions by gases and sectors.

GHG emissions and projections (Gg CO_2 equivalents)	KP Base Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2008-12	2013-17	2020	2025	2030
Distribution by gases (%):																					
CO2	76,0	76,3	79,2	77,8	78,4	78,7	80,3	79,2	77,6	81,0	81,0	81,3	81,0	79,8	80,3	80,7	80,6	81,4	81,3	80,8	80,4
CH4	8,2	8,2	7,9	8,6	8,6	8,7	8,1	8,5	9,5	8,1	7,9	7,8	7,9	8,5	8,2	8,0	8,1	7,8	8,2	8,4	8,6
N2O	15,3	15,3	12,5	12,5	11,9	11,5	10,7	11,1	11,4	9,7	9,8	9,6	9,8	10,3	10,2	10,0	10,0	9,8	10,1	10,4	10,7
HFCs	0,3	0,0	0,3	0,9	0,9	1,0	0,9	1,1	1,3	1,2	1,3	1,3	1,3	1,3	1,2	1,1	1,2	0,8	0,3	0,3	0,3
PFCs	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
SF6	0,2	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,1	0,0	0,1	0,1	0,1	0,1	0,1	0,2	0,1	0,2	0,1	0,1	0,1
Total	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**
Industrial gases (HFCs+PFCs+SF6)	0,5	0,1	0,4	1,0	1,0	1,0	1,0	1,2	1,4	1,2	1,3	1,3	1,3	1,4	1,3	1,3	1,3	1,0	0,4	0,4	0,4
Trends relative to the KP base year 1990/95:																					
CO2	100	100	115	101	104	103	113	102	89	110	108	110	107	99	101	102	104	104	99	95	92
CH4	100	100	106	103	106	105	105	101	102	101	98	97	96	97	96	94	96	92	93	91	91
N2O	100	100	90	81	78	75	75	72	66	65	65	65	64	64	64	63	64	62	62	61	61
HFCs	100	0	100	278	297	309	319	344	374	385	408	410	401	392	369	340	382	246	78	78	78
PFCs	100	0	100	3562	4406	4414	3851	3166	2765	2436	2146	2009	1914	1839	1773	1704	1848	1455	1112	1112	1112
SF6	100	41	100	55	28	23	29	31	32	33	34	34	34	34	64	107	55	104	55	55	55
Total	**100**	**100**	**110**	**98**	**101**	**99**	**107**	**98**	**88**	**103**	**102**	**102**	**100**	**94**	**96**	**96**	**98**	**97**	**93**	**89**	**87**
Industrial gases (HFCs+PFCs+SF6)	100	14	100	209	215	221	229	245	265	272	287	288	282	276	271	265	277	201	72	72	72
Distribution by IPCC main sector categories:																					
1. Energy	75	75	79	77	78	78	80	79	77	81	80	81	80	79	80	80	80	81	81	80	80
2. Industrial Processes	4	3	4	5	5	5	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3
3. Solvent and Other Product Use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4. Agriculture	19	19	16	16	15	15	14	15	16	14	14	13	14	15	14	14	14	13	14	14	14
6. Waste	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Trends relative to the KP base year 1990/95:																					
1. Energy	100	100	115	101	104	103	114	103	90	111	109	110	107	99	102	102	104	104	100	95	92
2. Industrial Processes	100	89	108	136	133	129	130	124	106	108	110	110	110	108	108	107	109	98	81	81	80
3. Solvent and Other Product Use	100	100	90	87	82	78	78	83	83	83	83	83	83	83	83	83	83	83	83	83	83
4. Agriculture	100	100	92	81	81	79	77	77	75	75	74	73	73	72	72	71	72	70	68	67	67
6. Waste	100	100	100	96	96	97	98	90	92	91	89	89	87	87	87	88	88	89	91	93	95
Total	**100**	**100**	**110**	**98**	**101**	**99**	**107**	**98**	**88**	**103**	**102**	**102**	**100**	**94**	**96**	**96**	**98**	**97**	**93**	**89**	**87**
Economic sector categories* - GHG emissions (Gg CO2 equivalents):																					
Energy	26620	26620	32758	26254	27612	27672	32540	26578	19588	30483	29564	30193	28820	24606	26031	26465	27223	27380	24529	21803	20214
Transport	10650	10650	12229	12561	12539	12722	13175	13589	13792	14032	14145	14207	14209	14146	14226	14314	14220	14619	15189	15560	15891
Agriculture, forestry and fisheries	15780	15780	14505	13101	13075	12675	12389	12214	12198	12135	12057	11974	11919	11874	11819	11681	11854	11465	11234	11048	11042
Business	9518	9237	9986	10464	10426	10005	10102	10087	9363	9359	9415	9449	9477	9506	9503	9485	9484	9278	8862	8872	8859
Domestic sector	5208	5208	5288	4319	4561	4335	4343	4231	4342	4164	3981	3853	3752	3664	3575	3469	3663	3257	3038	2912	2913
Waste	1547	1547	1548	1478	1479	1502	1515	1394	1423	1402	1384	1370	1354	1349	1353	1358	1357	1374	1405	1438	1466
Total	**69323**	**69042**	**76314**	**68177**	**69693**	**68910**	**74064**	**68092**	**60705**	**71575**	**70547**	**71046**	**69531**	**65146**	**66508**	**66772**	**67800**	**67371**	**64257**	**61634**	**60386**
Distribution by economic sectors (%):																					
Energy	38	39	43	39	40	40	44	39	32	43	42	42	41	38	39	40	40	41	38	35	33
Transport	15	15	16	18	18	18	18	20	23	20	20	20	20	22	21	21	21	22	24	25	26
Agriculture, forestry and fisheries	23	23	19	19	19	18	17	18	20	17	17	17	17	18	18	17	17	17	17	18	18
Business	14	13	13	15	15	15	14	15	15	13	13	13	14	15	14	14	14	14	14	14	15
Domestic sector	8	8	7	6	7	6	6	6	7	6	6	5	5	6	5	5	5	5	5	5	5
Waste	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Trends relative to the KP base year 1990/95:																					
Energy	100	100	123	99	104	104	122	100	74	115	111	113	108	92	98	99	102	103	92	82	76
Transport	100	100	115	118	118	119	124	128	130	132	133	133	133	133	134	134	134	137	143	146	149
Agriculture, forestry and fisheries	100	100	92	83	83	80	79	77	77	77	76	76	76	75	75	74	75	73	71	70	70
Business	100	97	105	110	110	105	106	106	98	98	99	99	100	100	100	100	100	97	93	93	93
Domestic sector	100	100	102	83	88	83	83	81	83	80	76	74	72	70	69	67	70	63	58	56	56
Waste	100	100	100	96	96	97	98	90	92	91	89	89	87	87	87	88	88	89	91	93	95
Total	**100**	**100**	**110**	**98**	**101**	**99**	**107**	**98**	**88**	**103**	**102**	**102**	**100**	**94**	**96**	**96**	**98**	**97**	**93**	**89**	**87**
Trends relative to the KP base year 1990/95 if adjustments for electricity exchange and temperature variations are taken into account:																					
Energy	100	100	93	81	79	77	75	71	61	70	71	68	67	65	66	66	67	65	65	55	51
Transport	100	100	115	118	118	119	124	128	130	132	133	133	133	133	134	134	134	137	143	146	149
Agriculture, forestry and fisheries	100	100	92	83	83	80	79	77	77	77	76	76	76	75	75	74	75	73	71	70	70
Business	100	97	105	110	110	105	106	106	98	98	99	99	100	100	100	100	100	97	93	93	93
Domestic sector	100	100	102	83	88	83	83	81	83	80	76	74	72	70	69	67	70	63	58	56	56
Waste	100	100	100	96	96	97	98	90	92	91	89	89	87	87	87	88	88	89	91	93	95
Total	**100**	**100**	**98**	**90**	**90**	**88**	**87**	**86**	**80**	**85**	**85**	**83**	**83**	**82**	**82**	**82**	**82**	**81**	**80**	**76**	**75**

* Definition of economic sectors		Sources/Sectors in the CRF/IPCC format			
Energy	Includes extraction, conversion, and distribution.	1A1 Fuel combustion activities.	1B Fugetive emissions from fuels.		
Transport	Military is included here.	1A3 Transport (fuel combustion)	1A5 Others (fuel combustion in military transport).		
Agriculture, forestry and fisheries	LULUCF is not included here cf. the Kyoto Protocol.	1A4c Fuel combustion in agriculture, forestry, and fisheries.	4. Agriculture		
Business	Includes production, building, construction, service, trade, F-gases and solvents.	1A2 Fuel combustion in production and building/construction.	1A4a Fuel combustion in commerce and service.	2. Industrial processes	3. Use of organic solvents.
Domestic sector		1A4b Fuel combustion in households.			
Waste	Includes landfills and sewage treatment. Incineration is included under energy.	6. Waste			

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