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Denmark's Greenhouse Gas Projections until 2012, an update including a preliminary projection until 2017

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Content

1 Introduction

This report presents the results of a project financed by the Danish Environmental Protection Agency. The purpose of the project is to make “with measures”- projections of the emissions from Danish sources of the greenhouse gases CO_2, CH_4, N_2O, HFCs, PFCs and SF_6. The ‘with measures’ projection encompasses currently implemented and adopted policies and measures.
The time period covered is from 1972, the first year detailed Danish energy statistics were produced, until the first commitment period (2008-2012) under the Kyoto Protocol to the Climate Convention. A preliminary projection is also made for the second commitment period (2013-2017), but here no projections are available for the agricultural sector and the emissions from this sector have therefore been kept equal to the emissions in the first commitment period.
Estimations of HFCs, PFCs and SF_6-emissions and projections have are base upon a new report [20]. These estimations cover only the period from 1993 until 2020.
Only emissions caused by human activities are included in the calculations. However, it can sometimes be difficult to draw the borderline between emissions from nature and anthropogenic emissions.

Due to small differences between the methodology used in this project and the methodology (CORINAIR) used by the National Environmental Research Institute for the purpose of annual reporting the estimated emissions presented for the period 1990-2000 may deviate a little from the official emission estimates reported to the EU and the Climate Convention (UNFCCC). Therefore the GHG emission estimates presented in this report for the period until 2000 should only be seen as an illustration of the order of magnitude. This is also the case for the parts of the trend analysis in Chapter 2, which are based on the historic data coming from this project.

The description of the emissions in the report is structured according to the IPCC sectors:
Energy (chapter 3)
Industrial processes (chapter 4)
Agriculture (chapter 5)
Land use change & forestry (chapter 6)
Waste (chapter 7)

The NMVOC emission from solvent use is included as a source of CO_2 emission.
A separate chapter is dedicated to each of these sectors. However, the report starts with a summary (chapter 2) of the emissions with a section for each of the pollutants treated. At the end of each of these sections the main differences between the present calculation and the values in Denmark’s Second National Communication on Climate Change [1] are described shortly. For each of the pollutants the development of the emissions in the period 1972-2012 and the various emission targets in Danish sector plans or international conventions are shown on a figure. Below the figures the emissions for the main emitting sectors are shown in a table. The years shown

in these tables are not the same for all pollutants. When a column is marked with "2010" it means that the values in the columns are averaged over the first commitment period 2008-2012. "2015" means similarly the average for the second commitment period 2013-2017.
It is not possible in this report to present all the data from the emission calculations. The data is contained in an EXCEL notebook model. The Appendix 1 contains a table with time-series for 1975-2017 for the greenhouse gases CO_2, CH_4 and N_2O for all emitting sectors (see table 28 to table 30). In Appendix 2 the results of the projections 2000-2017 are shown in the IPCC/CRF Sectoral Tables format in CO_2 equivalents for each greenhouse gas and in total (only source and sink categories with greenhouse gas emissions or removals are shown). If the reader needs additional information, please ask the author.

The model is structured as a set of worksheets for the primary energy consuming sectors and the model contains similar sets for each of the pollutants. Additional sheets have been included for the relevant pollutants, where emissions originate from non-combustion processes. Each of these spreadsheets contains time-series for the emissions from each of the primary fuels consumed in the sector.

2 Summary of emissions

The following sections give a summary of the emissions of each of the gases covered. Detailed time-series for the gases CO_2, CH_4 and N_2O can be found in table 28 to table 30 in Appendix 1. In these tables the time-series are disaggregated in the emitting sectors and a total is shown. For CO_2 from fossil fuel combustion both totals without and with corrections for electricity import/export and inter-annual temperature variations are shown. The aggregate anthropogenic carbon dioxide equivalent (CO_2-eq.) emission of the greenhouse gases CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) are calculated by multiplying the emissions of each of the greenhouse gases with the 100 years global warming potentials (GWP) shown in Table 1 [2]. These GWPs are recommended by IPCC in the Second Assessment Report and shall be used under the Kyoto Protocol. The GWP of 310 for N_2O means e.g. that the global warming caused by 1 tonne of N_2O is the same as the global warming caused by 310 tonnes of CO_2.

Table 1. Global warming potentials

Species	Chemical Formula	GWP
Sulphur hexafluoride	SF_6	23900
Perfluoromethane	CF_4	6500
Perfluoroethane	C_2F_6	9200
Perfluoropropane	C_3F_8	7000
Methane	CH_4	21
Nitrous oxide	N_2O	310
HFC-23	CHF_3	11700
HFC-32	CH_2F_2	650
HFC-43-10	$C_5H_2F_{10}$	1300
HFC-125	C_2HF_5	2800
HFC-134a	CH_2FCF_3	1300
HFC-143a	$C_2H_3F_3$	3800
HFC-152a	$C_2H_4F_2$	140
HFC-227ea	C_3HF_7	2900
HFC-236fa	$C_3H_2F_6$	6300
HFC-245ca	$C_3H_3F_5$	560

In the Kyoto Protocol to the Climate Convention, the parties to the Convention in Kyoto in 1997 agreed, as a first step, to reduce the greenhouse gas emissions of the industrialized countries in 2008 to 2012 by at least 5 per cent in comparison to the 1990 level. According to the agreement, the EU is to contribute a total reduction of 8 per cent. Since then, the EU Member States have agreed to an internal burden sharing that commits Denmark to a reduction of 21 per cent.

With the latest updated GHG emission inventory from the National Environmental Research Institute (NERI), Denmark's commitment to reducing emissions of greenhouse gases by 21 per cent in the first commitment period means that emissions are to be reduced from 69.7 Mt CO_2-eq. in the base year to an average of 55.0 Mt CO_2-eq. in the first commitment period 2008 and 2012. The result of the updated projections for emissions of greenhouse gases until 2012 carried out in this project shows that Denmark is expected to emit an average of 80.1 Mt CO_2-eq. in the first commitment period.

The results are summarized in Table 2, which shows that the emission of CH_4 decreases from 5.8 Mt CO_2-eq. in 1990 to 5.0 Mt CO_2-eq. in "2010". The emissions of N_2O also decrease, from 10.8 Mt CO_2-eq. in 1990 to 8.7 Mt CO_2-eq. in "2010". For the industry gasses HFCs, PFCs and SF_6 there is an increase from 0.3 Mt CO_2-eq. in the base year to 0.7 Mt CO_2-eq. in "2010".

Table 2. Denmark's expected GHG emissions in 2008-2012 and the deficit when comparing with the Kyoto target for the first commitment period in the Kyoto Protocol.

Mio. tonne CO_2-equivalents	Base year 1990[1]	2000	"2010"[2]	"2015"[3,4]
CO_2	52,6	52,8	65,6	64,4
Methane (CH_4)	5,8	5,8	5,0	4,7
Nitrous oxide (N_2O)	10,8	9,1	8,7	8,7
HFCs, PFCs and SF_6	0,3	0,8	0,7	0,5
Total emissions of greenhouse gases	69,7	68,4	80,1	78,3
Kyoto target: -21% in "2010"compared to 1990			*55,0*	
Deficit			25,0	
Electricity-export(+)/import(-)	-6,3	-0,7	+9,9	+9,1
Deficit without net-electricity export			15,1	

[1] The base year for CO_2, CH_4, and N_2O is 1990. In accordance with the Kyoto Protocol Denmark has chosen 1995 as the base year for HFCs, PFCs and SF_6.
[2] "2010" are used for the average emissions in the first commitment period 2008-2012.
[3] "2015" are used for the average emissions in the second commitment period 2013-2017.
[4] No new projections have been made for the emissions of methane and nitrous oxide from agriculture for the period 2013-2017. The emissions from the first commitment period have been used here.

The base year estimation in this project is 0.5 Mt CO_2-eq. lower than the estimate shown in Table 2 coming from the use of the CORINAIR methodology as mentioned in Chapter 1. Similarly is our estimate for the year 2000 a bit higher (0.2 Mt CO_2-eq.) than the CORINAIR value shown in Table 2.

As show in Table 2 the total emissions depend strongly on the CO_2 emissions from the fuel used for electricity export. Of the total emission of 80.1 Mt CO_2-eq. in the first commitment period 9.9 Mt CO_2-eq. originates from electricity export. The calculation in the model of the emissions from electricity export is based on the amount of fuel used on the power plants producing for export. The updated energy projection described in [4] expects an electricity export gradually increasing to about 12 TWh in 2010 corresponding to an emission of 9.9 Mt CO_2-eq.

According to Table 2 the Danish deficit is now 25 Mt CO_2-eq.when the projection is compared to the Danish Kyoto target in the first commitment period. This deficit has increased compared to the former projection [58] where the deficit was 1.8 Mt CO_2-eq. when the base year emission was corrected for net-electricity exports (i.e. electricity import in 1990) and measures to exclude the effect of the electricity export 2008-12 were included. A recalculation of the base year emissions by NERI in April 2002 gave a 0.4 Mt CO_2 -eq. raise to the deficit. The increase in the deficit of 22.8 Mt CO_2-eq. shown in this report is composed of 5.0 Mt CO_2-eq. from not correcting the emissions in the base year 1990 and 9.9 Mt CO_2-eq. from not including measures to exclude the effect of the electricity export 2008-12. The main reason for the remaining increase of 7.9 Mt CO_2-eq. is changes in the energy projection. The main changes in the energy baseline compared to the one used in the 2001 projection is the following:

- Primary energy consumption in industry, manufacturing and construction in 2012 is projected to be 114 PJ compared to 95 PJ in the former projection. This has caused the deficit to increase about 1.1 Mt CO_2. Increased use of diesel in agriculture in the new projection will cause an increase of 0.5 Mt CO_2, whereas an expected decrease in the fuel consumption in domestic and service sector will reduce emissions with 0.2 Mt CO_2. That total increase in the deficit from these contributions is then 1.4 Mt CO_2.

- Changed assumptions for electricity and heat production have increased the deficit with 2.0 Mt CO_2. This increase in the sum of an increase of 1.6 Mt CO_2 on large power plants, 0.3 Mt CO_2 on decentral power plants, and 0.1 Mt CO_2 on district heating plants. The reduction in the expected number of wind turbines is one of the explanations for this increase.

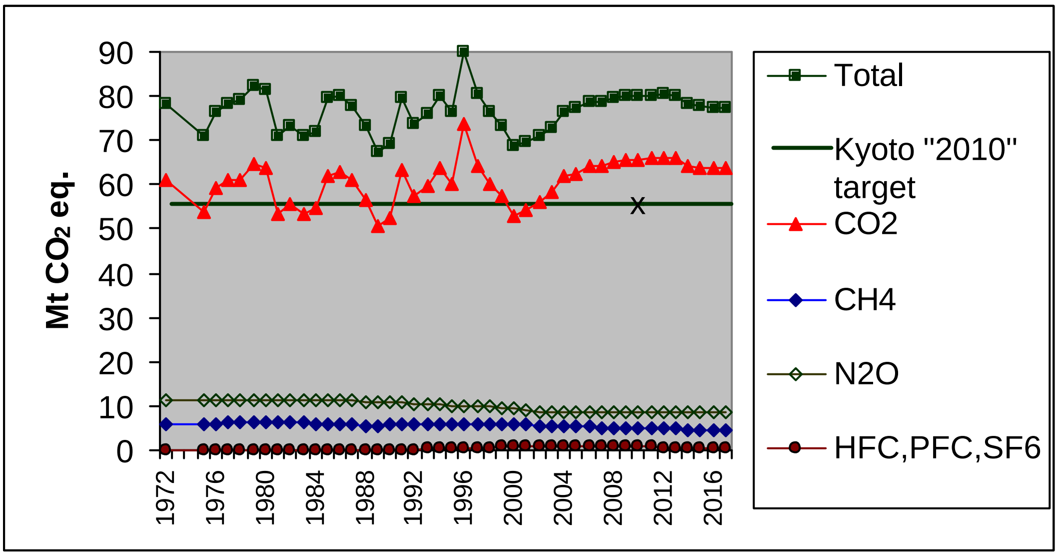
- The expected electricity export in 2012 has now been reduced to 12 TWh from the 17 TWh in the former projection [58]. The emissions caused by the production of electricity for export has therefore decreased from 12.9 Mt CO_2 to 9.9 Mt CO_2 in the first commitment period. This decrease of 3.0 Mt CO_2 is part of the increased deficit. With the same fuel consumption for electricity production and reduced exports the old deficit would have been these 3.0 Mt CO_2 larger.

- The primary energy consumption for road transport in 2012 is projected to be 180 PJ compared to 165 PJ in the former projection [58]. This causes an increase in the deficit of 0.8 Mt CO_2-eq. This includes an increase of 0.3 Mt CO_2 from extra diesel bought in Denmark by foreign drivers and 0.1 Mt CO_2-eq. from the increase in nitrous oxide emissions related to fuel consumption in cars with catalytic converters.

- The CO_2 emission from the use of natural gas on the platforms in the North Sea has increased about 0.7 Mt CO_2 compared to the former projection. The reason for this increase is primarily new extraction methods, which increase the amount of resources that it is possible to extract from the fields.

In the calculation of the emissions in Figure 1 and Table 2, the emissions from flaring, emissions of CO_2 from plastics in waste incinerated and the reduction of emissions due to the growth of new forest planted after 1990 are included. The sequestration in forest existing before 1990 is not included. The emissions from international air transport and international bunkers are not included. The emissions from road transport are based on gasoline and diesel sold in Denmark, and therefore not corrected for border trade.

Figure 1. 2000-2017: Total emissions of CO_2 equivalents from Denmark if no new measures are introduced.



2.1 Emissions of CO_2

The main source of CO_2 emissions from Denmark is the combustion of fossil fuels. The only other source contributing is the mineral sector and CO_2 from the decomposition of NMVOCs emitted from the use of solvents. It is shown in section 4.1 that the total emission from the mineral sector increases from 1 Mt CO_2 in 1990 to 1.5 Mt CO_2 in 2010. The emission increased already to 1.5 Mt CO_2 in 2000 and is expected to be constant until 2010, since the cement producing capacity, emitting 1 Mt CO_2 in 1990 and 1.4 Mt CO_2 in 2000, is running at maximum capacity. The emission from the production of yellow bricks and lime is only about 0.1 Mt CO_2.

The CO_2 emission from the solvent sector declines from 0.124 Mt CO_2 in 1990 to 0.069 Mt CO_2 in 2010. This is based on the assumption that 85% of the weight of the NMVOCs emitted from solvents results in an emission factor of 3.12 kg CO_2 /kg NMVOC. The emission projection for NMVOC from 2001 until 2012 now uses the updated projection in [64], whereas the historical values are the same as in the former projection [58], since these numbers are still used in the Danish CORINAIR reporting.

In the Danish energy plan "Energi21", the goal is to reduce the emissions of CO_2 corrected for net electricity export and temperature with 20% of the 1988 level in 2005. This total is calculated in a different way than done for the Kyoto Protocol above. The national CO_2-target includes emissions from international air transport but excludes emissions from cement, lime and yellow bricks production and from flaring and plastics in waste incinerated as well as removals by sinks. The emissions from road transport are based on gasoline and diesel consumed in Denmark, and therefore corrected for border trade (according to Table 3, cars from other countries bought fuel equivalent to an emission of 0.2 Mt CO_2 in 1988). The category other in Table 3 covers fuel use for transport in the military and the use of gasoline for off-roaders at power plants, railways and in the household sector. Done in this way, the total emission in 1988 was 61.1 Mt CO_2. The emission target for 2005 is therefore 48.8 Mt CO_2 (shown on Figure 2 as the upper horizontal line).

As shown on Table 3, the total emission in 2005 will be 52.3 Mt CO_2 calculated using the energy projection in the latest energy projection from the Danish Energy Agency [4]. This is 3.5 Mt CO_2 or 7.2% above the Energy21 target. Figure 2 shows that the total emission in 2002 is closer to the Energy21 target; this year the emissions is expected to be 51.3 Mt CO_2 or 5.1% above the target.

The sector with the largest increase in CO_2 emission is road transport, increasing from 8.8 Mt CO_2 in 1988 to 13.0 in "2010". International air transport, which as mentioned above is also included in the total in Figure 2, increases from 2.4 Mt CO_2 in 2000 to 3.2 Mt CO_2 in "2010". The emission from central power plants in Table 3 is the actual uncorrected emission. According to the next line in the table, the corrected CO_2 emission in "2010" will be 9.9 Mt CO_2 lower.

In 1998 the CO_2 emission factor regarding waste incineration was revised to take into account CO_2 emissions from plastic in the waste. Assuming 6.4% of plastic in the waste (see section 3.2) the emission from the combustion of waste was rising from 0.29 Mt CO_2 in 1990 to 0.60 Mt CO_2 in 2000, and is expected to be 0.72 Mt CO_2 in 2010 (see Table 3).

Figure 2. Corrected CO_2 emissions compared to Danish Energy21 Plan

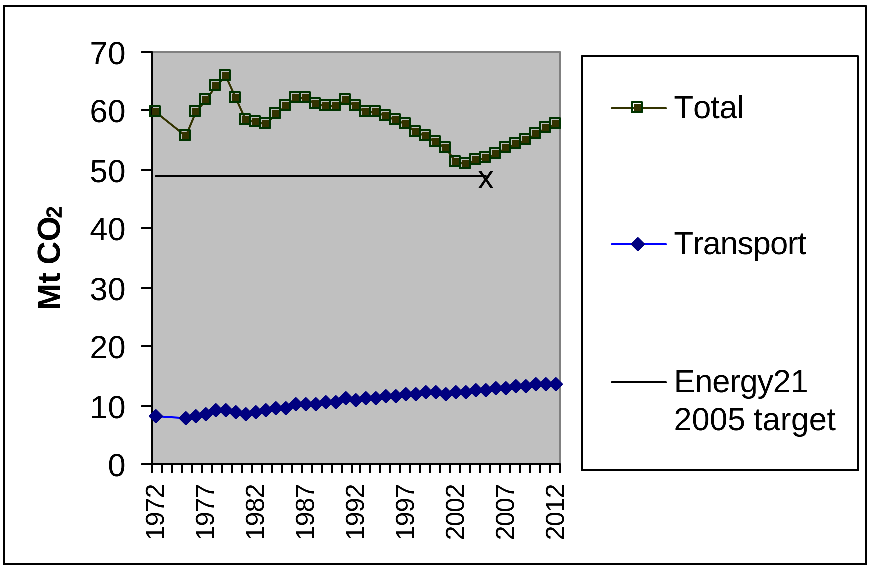


Table 3. Emission of CO_2 by sectors

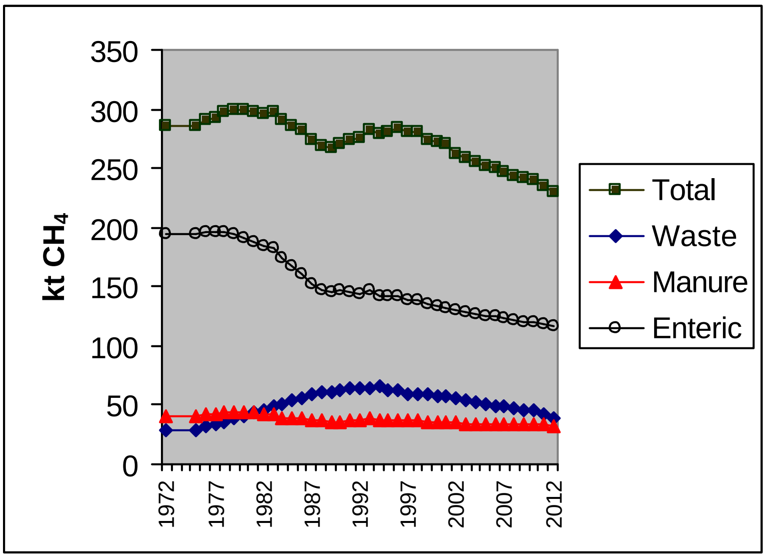
kt CO_2	1988	1990	2000	2005	"2010"	"2015"
Central power	25.4	22.7	19.1	27.0	28.7	27.3
Net electricity import	3.6	6.3	0.7	-10.3	-9.9	-9.1
Decentral power	0.1	0.2	3.2	2.5	2.3	2.1
District heating plants	2.1	1.5	0.5	0.6	0.9	1.0
Industry	6.2	6.1	6.0	6.5	7.1	7.7
Agriculture & fishery	2.2	2.3	2.4	2.5	2.6	2.6
Off-shore combustion	0.5	0.5	1.4	2.5	2.5	2.1
Refineries & gassupply	0.9	0.9	1.0	1.0	1.0	1.0
Residential	6.1	4.9	4.0	4.0	3.8	3.7
Service	1.6	1.4	0.9	0.9	0.9	1.0
Temperature correction	0.3	1.9	1.3			
Road transport (sales)	8.8	9.4	11.3	12.1	13.0	13.4
Border trade	0.2	0.1	0.0			
Other transport	1.4	1.3	1.0	0.9	0.9	1.0
Other	0.1	0.1	0.1	0.2	0.2	0.1
International air	1.8	1.8	2.4	2.8	3.2	3.7
Flaring	0.3	0.2	0.6	0.6	0.6	0.5
Mineral products	1.0	1.0	1.5	1.5	1.5	1.4
Plastics in waste incinerated	0.3	0.3	0.6	0.7	0.7	0.7
Bunkers	2.9	3.1	4.3	3.6	3.6	3.6
Solvents conversion	0.1	0.1	0.1	0.1	0.1	0.1
New forest	0.0	0.0	-0.1	-0.2	-0.3	-0.4
Energy21 Total	61.1	60.9	54.6	52.3	56.4	56.8

2.2 Emissions of CH_4

The main part of the CH_4 emissions originates from the animals in the agricultural sector (see chapter 5). The decrease in the CH_4 emissions from enteric fermentation in the period 1980 to 2000 continuing until 2012 as shown on Figure 3 is caused by the decrease in the number of cattle. For the same reason the CH_4 emissions from manure management also decreases n this period, but are offset by the increased emissions from the increased number of pigs. As mentioned in section 5.1.2 the emission factors for manure management for Denmark has been changed since Denmark's Second National Communication from using emission factors for temperate to cool areas. This change has reduced the CH_4 emission from manure management considerably, by more than a factor of three.

The second largest CH_4 emitter is the landfills (see section 7.1). The emissions from landfills had a maximum in 1992. Since then the emission has declined, due to the stop for landfilling of combustible waste in 1996, the decrease due to the ageing of the landfills and the increasing number of landfill gas collection plants.

Figure 3. Emissions of CH_4 from Denmark



The CH_4 emission from energy combustion has increased since the introduction of decentralised power plants using gas engines, where some of the natural gas is not combusted (see section 3.2). The CH_4 emission in Table 4 from residential & service is from the use of wood and straw in small individual combustion units.

The calculation of the CH_4 emission has changed since the Second Danish Communication [1]. The total CH_4 emission in 1990 was then calculated to be 424 kt CH_4 (the value is now 270.9 kt CH_4 for 1990). The main reason is the change for animal manure, where the emission has dropped with a factor of three, as described in section 5.1.2. New figures for the amount of waste landfilled have also decreased the emission in 1990 from 71 kt CH_4 to 64.0 kt CH_4. The emissions of CH_4 are not corrected for electricity import/export. Table 4 shows the CH_4 emissions both from the energy sectors and the non-energy sector.

Table 4. Emissions of CH_4 by sectors

kt CH_4	1990	2000	2005	"2010"
Central power plants	0.4	0.4	1.2	1.2
Decentralised power plants	0.9	16.0	11.6	10.6
District heating plants	0.4	0.3	0.4	0.4
Industry	1.2	1.4	1.5	1.6
Agriculture & fishery	0.8	2.0	2.1	2.2
Oil & gas extraction	0.2	0.5	0.9	0.9
Refineries & gas supply	0.1	0.1	0.1	0.1
Residential & Service	7.3	8.5	9.3	9.4
Road transport	2.5	2.7	2.1	1.4
Other transport	0.3	0.3	0.3	0.3
Enteric fermentation	146.5	134.2	125.8	119.5
Animal manure	36.6	38.6	37.2	36.6
Reduction by biogas plants	-0.3	-2.5	-3.6	-3.8
Landfills	64.0	67.8	61.2	53.3
Reduction by landfill plants	-1.7	-10.3	-11.4	-9.8
Gas networks leakages	8.4	8.4	8.4	8.4
Refineries	0.04	0.04	0.04	0.04
Coal storages	3.3	3.7	4.6	4.8
Total	270.9	272.1	251.7	237.3

2.3 Emissions of N_2O

As shown on Figure 4 the major part of the N_2O emissions originate from agricultural soils (se section 5.2). The main reason for the decrease on the figure from 1990 to 2003 is the combined action of the Danish Action Plan for Sustainable Agriculture and "Vandmiljøplan II". The projection has been updated to take into account the impacts of the midterm evaluation of vandmiljøplan II and the Danish action plan to reduce the evaporation of ammonia from agriculture.

Figure 4. Emissions of N_2O from Denmark

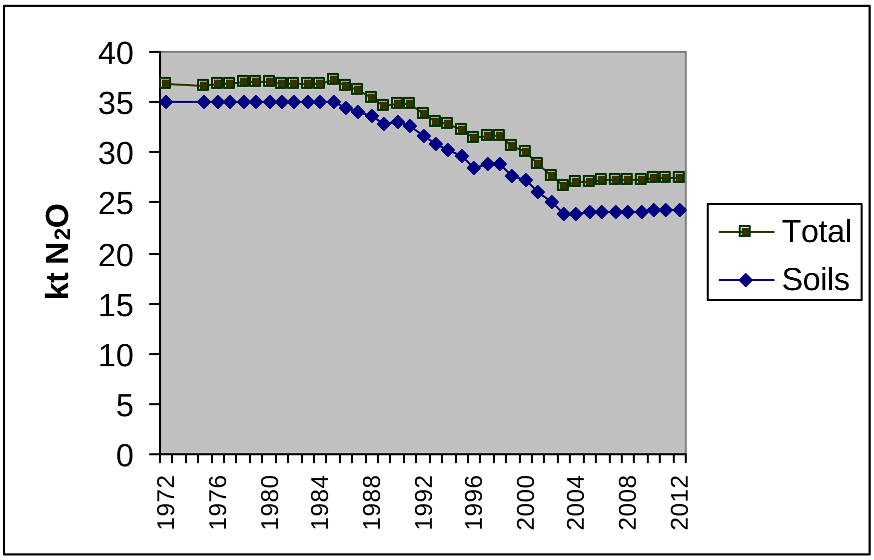


Table 5 shows the increase of the N_2O emission from road transport from 0.4 kt N_2O in 1990 to 2.0 kt N_2O in 2010 due to the introduction of 3-way catalytic converters on the gasoline cars. Table 8 shows that the emission factor for N_2O increases with a factor of five from 1991 to 2010.

Table 5. Emissions of N_2O by sectors

kt N_2O	1990	2000	2005	"2010"
Power plants	0.8	0.8	1.1	1.1
All industry	0.3	0.3	0.3	0.3
Residential & Service	0.2	0.2	0.2	0.2
Road transport	0.4	1.5	1.9	2.0
Other transport	0.0	0.0	0.0	0.0
Synthetic fertilisers	7.6	4.7	3.4	3.4
Animal fertilisers	3.6	3.5	3.6	3.7
Nfix+waste+deposition	2.5	2.3	2.2	2.1
Manure management	2.7	2.3	2.3	2.4
Reduction by biogas plants	-0.0	-0.04	-0.05	-0.06
Animal grazing	0.9	0.9	0.9	0.9
Crop residues	6.4	6.2	6.3	6.3
Histosols	0.1	0.1	0.1	0.1
Leaching & runoff	9.2	7.2	5.2	5.2
Total	34.9	30.1	27.6	28.1

The procedure for the calculation of the N_2O emission has changed since the Denmark's Second Communication [1]. However the totals have changed very little. In [1] the emission in 1990 was 34 kt N_2O and the emission in 2000 and 2010 was 28 kt N_2O. The emissions of N_2O are not corrected for electricity import/export.

2.4 Emissions of HFCs, PFCs and SF_6

Section 4.1.3 contains a projection of the emissions of three groups of greenhouse gases, perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and hydrofluorocarbons (HFCs) through to the year 2020.
The emission levels have decreased compared to former reports [58] for several reasons:
1) Because the actual emissions have been corrected for the greenhouse gases contained in the exported and imported appliances.
2) A tax has been introduced on these three groups of gases amounting to 1/10th of their GWP in Table 1 up to a maximum of 400 kr/kg.
3) New Danish legislation containing dates for outphasing import, production and use of these industrial greenhouse gasses.
4) New rules for decommissioning, where the GHG in refrigerators, foam etc. are destroyed instead of emitted to the atmosphere. This is a mayor reason for the decrease in the present projection compared to the last one in [58]. The difference with the old calculation is especially large in the second commitment period, 2013-17 (marked as "2015").
5) Further there have been changes in the leak-rates for commercial and mobile refrigerants.

Table 6. Emissions of HFCs, PFCs and SF_6

Mt CO2 equivalents	1995	2000	2005	"2010"	"2015"
HFCs	0.24	0.73	0.76	0.64	0.37
PFCs	0.00	0.03	0.02	0.02	0.02
SF6	0.11	0.06	0.03	0.05	0.10
Total	0.35	0.82	0.81	0.71	0.50

As shown in
Table 6 the total emissions in 1995 of these gases have changed to 0.35 Mt CO_2 eq. since Denmark's Second National Communication [1], where the emission in 1995 was 0.42 Mt CO_2 equivalents. No emission projection was made for HFCs, PFCs and SF_6 in [1]. The calculations are now done according to the 1996 IPCC Revised Guidelines for National Greenhouse Gas Inventories. The emissions are corrected for the greenhouse gas contained in the exported (and imported) appliances.

3 Energy

According to the 1996 IPCC Revised Guidelines for National Greenhouse Gas Inventories this chapter is divided into two parts: the emission from combustion of fuels and the fugitive emissions from fossil fuels.

There is a change in the assumptions on the composition of the electricity production in the present projection and in the former projection [58]. The total capacity of Danish wind turbines is now not expected to increase above the 3000 MW reached in 2003. The reason is that the on-shore capacity will stay constant and that no off-shore wind parks after Horns rev and Rødsand in 2003 are included in the baseline, due to that economic condition for the future off-shore wind parks are not yet resolved. Some other subsidies have also been cancelled: One example is biogas where the production biogas from animal manure therefore only will increase about 50% from 2000 until 2012 since no new biogas plants are expected after 2004.

3.1 Fuel Combustion Activities

The emissions from the combustion of energy are based on the data for energy consumption in Denmark for the period 1972-2017 (there is a minor inconsistency in the historical use of fossil energy of less than 0.3 PJ). The Danish Energy Agency produced an EXCEL pivot-table, in a standard format, containing the historic energy data until 2001 and the latest projection of the future primary energy consumption, according to the follow-up on the Danish energy plan "Energi21" [4]. The emission model at Risø is automatically updated, when the Danish Energy Agency produces a new pivot-table.

The projection of the energy consumption is based on the projection of the production until 2010 in the report from the Danish Ministry of Finance: *Økonomisk Oversigt, januar 2002* supplemented with a longer projection from the Danish Ministry of Finance: *Finansredegørelse 2001.* The latest price projections for crude oil and coal are based on IEA: *World Energy outlook 2002, September 2002*. The economic projection is transformed into a projection of the energy consumption using a number of models in the Danish Energy Agency such as the EMMA-model. The RAMSES model is then used to transform the demand for electricity and district heat into fuel demand at the power plants.
According to Table 2 the Danish deficit is now 25 Mt CO_2-eq. when the projection is compared to the Danish Kyoto target in the first commitment period. This deficit has increased compared to the former projection [58] where the deficit was 1.8 Mt CO_2-eq. when the base year emission was corrected for net electricity exports and measures to exclude the effect of the electricity export 2008-12 were included. A recalculation of the base year emissions by NERI in April 2002 gave a 0.4 Mt CO_2 -eq. raise to the deficit. The increase in the deficit of 22.8 Mt CO_2-eq. shown in this report is composed of 5.0 Mt CO_2-eq. from not correcting the emissions in the base year 1990 and 9.9 Mt CO_2-eq. from not including measures to exclude the effect of the electricity export 2008-12. The main reason for the remaining

increase of 7.9 Mt CO_2-eq. is changes in the energy projection. The main changes in the energy baseline compared to the one used in the 2001 projection is the following:

- Primary energy consumption in industry, manufacturing and construction in 2012 is projected to be 114 PJ compared to 95 PJ in the former projection. This has caused the deficit to increase about 1.1 Mt CO_2. Increased use of diesel in agriculture in the new projection will cause an increase of 0.5 Mt CO_2, whereas an expected decrease in the fuel consumption in domestic and service sector will reduce emissions with 0.2 Mt CO_2. That total increase in the deficit from these contributions is then 1.4 Mt CO_2.

- Changed assumptions for electricity and heat production have increased the deficit with 2.0 Mt CO_2. This increase in the sum of an increase of 1.6 Mt CO_2 on large power plants, 0.3 Mt CO_2 on decentral power plants, and 0.1 Mt CO_2 on district heating plants. The reduction in the expected number of wind turbines is one of the explanations for this increase.

- The expected electricity export in 2012 has now been reduced to 12 TWh from the 17 TWh in the former projection [58]. The emissions caused by the production of electricity for export has therefore decreased from 12.9 Mt CO_2 to 9.9 Mt CO_2 in the first commitment period. This decrease of 3.0 Mt CO_2 is part of the increased deficit. With the same fuel consumption for electricity production and reduced exports the old deficit would have been these 3.0 Mt CO_2 larger.

- The primary energy consumption for road transport in 2012 is projected to be 180 PJ compared to 165 PJ in the former projection [58]. This causes an increase in the deficit of 0.8 Mt CO_2-eq. This includes an increase of 0.3 Mt CO_2 from extra diesel bought in Denmark by foreign drivers and 0.1 Mt CO_2-eq. from the increase in nitrous oxide emissions related to fuel consumption in cars with catalytic converters.

- The CO_2 emission from the use of natural gas on the platforms in the North Sea has increased about 0.7 Mt CO_2 compared to the former projection. The reason for this increase is primarily new extraction methods, which increase the amount of resources that it is possible to extract from the fields.

The energy consuming sectors used in the calculation of the emissions from the energy sector is shown in Table 7. The energy consumption and the emissions from power plants are disaggregated into two groups, one above 25 MW electric capacity and one below 25 MW. The reason for this is that the Danish Ministry for Economy and Business Affairs restricts the total emissions of SO_2 and NO_x from the power plants above 25 MW to be below a certain value each year [16].

Table 7 shows the fuel type used in the emission calculations. Minor amounts of brown coal were included in the category "coal". Woodchips, fuelwood, wood pellets and wood waste were added and called "wood". The fuel type "energy crops" consist of fish oil, elephant grass and willow. The fuel types based on biomass do not contribute to the CO_2 emission due to the recirculation of the carbon - but other pollutants are emitted from the combustion of biomass as shown in Table 8.

Table 7. Energy sectors and fuel types used in the calculation

Energy sectors
Power plants > 25 MW
Power plants < 25 MW
Electricity export
District heating plants
Industry
Refineries
Oil- & gas extraction
Flaring
Town gas plants
Agriculture
Fishery
Households
Service
Road transport
Border trade
Rail transport
Sea Transport
Domestic air transport
Military transport
Bunkers
International transport

Fuel types
Natural gas
Refinery gas
Town gas
LPG
Aviation gasoline
Gasoline
Kerosene
Gasoil/diesel
Residual oil
Orimulsion
Petroleum coke
Coal
Coke
Waste
Straw
Wood
Energy crops
Biogas

3.2 Emission factors

All emission factors for fuel combustion used in the calculations are shown in Table 8. The table is organised with a set of emission factors for each group of energy consuming sectors. The units for the emission factors are always in kg of emission per GJ of fuel combusted. When tonnes are converted to joules in Danish energy statistics, net calorific values are applied as recommended by IPCC. In each sector there are individual emission factors for all fuels used in the sector. Table 8 also shows the decrease over time for some emission factors. If a cell in the table is blank it means that the emission factor has not changed and the value above is used. The emission factors have been updated so that the emission factors in the CORINAIR database are in agreement with the emission factors used in the projections.

Since not all the combustible waste is of biomass origin a CO_2 emission factor for the combustion of waste is estimated in order to take the plastic content of the waste into account. It is assumed that 6.4% of the waste is plastic [9], that the calorific value of plastic is 42.4 GJ/t and that the carbon content is 20 kg C/GJ. The resulting emission factor is then 18.95 kg CO_2 /GJ.

The high CH_4 emission factor for decentralised power plants is based on the assumption that 3% of the natural gas in the gas engines is not combusted [10]. Table 8 also contains separate emission factors for natural gas turbines and for natural gas engines.

The historic emission factors for road transport are calculated with the COPERT II model [11,12]. The output from COPERT II for the total emission of each pollutant for each year were divided with the total fuel consumed for each of the road vehicles categories: gasoline cars, diesel cars, light duty diesel vehicles, heavy duty diesel vehicles, and LPG cars.

For the future emission factors in 2005 and 2010 the information on deterioration factors, future cold start emission levels and updated emission factors for EURO I-IV vehicles in the background material for the COPERT III model was used [13]. The implementation of this emission information especially affects the catalyst car emissions.

The emission factors used for railways are the factors from COPERT II for heavy duty vehicles above 16 tonnes at highway driving conditions.

Emission factors for air transport:
Combining relevant air traffic statistics, energy use and emission factors, an energy and emission calculation model for the Danish air traffic was developed at the National Environmental Research Institute [12] following the CORINAIR methodology. In this model, energy use and emissions from both the domestic and international air traffic for LTO (Landing and Take Off) and the cruise activity are covered in four sub categories. The Danish part of the total air traffic energy use is defined by the UNECE convention as the LTO energy use. At the same time the cruise activity covering all air transport activity above 1000 m is defined as international transport. This allocation procedure is made for all pollutants except for CO_2. In the latter case the Danish emission part is defined as the CO_2 contribution from all domestics flights during both LTO and cruise.

To end up with the final aggregated air traffic emission factors, the energy use and the emissions are estimated for the four sub-categories mentioned above.

As a start all take-off's from Danish airports are divided into the number of LTO's carried out by different representative aircraft types. The next step is to multiply the fuel consumption factor for each aircraft type with the corresponding number of LTO's, giving the energy use totals for domestic and international LTO's, respectively. The total energy use by domestic and international cruise is then calculated as the difference between the total fuel sold for aviation in Denmark and the total calculated fuel used for LTO.

The LTO emissions are calculated by combining LTO emission factors and -numbers for all representative aircraft. For cruise the emissions are estimated as the fuel use times fuel related emission factors. The aggregated emission factors in Table 8 are finally found as the total emissions divided with the total energy use for LTO and cruise, respectively.

Emission factors for off-roaders
Emissions from other mobile sources and machinery in agriculture, forestry, industry and household & gardening using diesel oil, gasoline and LPG are estimated following the guidelines in CORINAIR. Information on the stock of different machine types and their respective load factors, engine sizes, annual

working hours and emission factors is combined in a computer model [12] in order to calculate the total emissions.

Table 8. Emission factors used for fuel combustion

Sector	Fuel	Valid in period	CO2 kg/GJ	N2O kg/GJ	CH4 kg/GJ	NMVOC kg/GJ
Public Power	Coal	1972-	95.0	0.0030	0.0015	0.0015
	Orimulsion	1995-	80.0	0.0020	0.0030	0.0030
	Waste	1972-	18.95	0.0040	0.0060	0.0090
	Straw	1972-	0.0	0.0040	0.0320	0.0480
	Wood	1972-	0.0	0.0040	0.0320	0.0480
	Energy crops	1972-	0.0	0.0020	0.0015	0.0015
	Petroleum coke	1972-	92.4	0.0030	0.0015	0.0015
	Residual oil	1972-	78.0	0.0020	0.0030	0.0030
	Diesel oil	1972-	74.0	0.0020	0.0015	0.0015
	Natural gas	1972-	56.9	0.0010	0.0025	0.0025
Decentral Power Plants (+autoproducers)	Coal	1972-	95.0	0.0030	0.0150	0.0150
	Waste	1972-	18.95	0.0040	0.0060	0.0090
	Straw	1972-	0.0	0.0040	0.0320	0.0480
	Wood	1972-	0.0	0.0040	0.0320	0.0480
	Energy crops	1972-	0.0	0.0020	0.0015	0.0015
	Residual oil	1972-	78.0	0.0020	0.0030	0.0030
	Gas oil	1972-	74.0	0.0020	0.0015	0.0015
	Natural gas engines	1987-	56.9	0.0010	0.5983	0.0040
	Biogas engines	1987-	56.9	0.0010	0.2792	0.0040
	Natural gas turbines	1987-	56.9	0.0010	0.0040	0.0040
District Heating Plants	Coal	1972-	95.0	0.0030	0.0150	0.0150
	Waste	1972-	19.0	0.0040	0.0060	0.0090
	Straw	1972-	0.0	0.0040	0.0320	0.0480
	Wood	1972-	0.0	0.0040	0.0320	0.0480
	Energy crops	1972-	0.0	0.0020	0.0015	0.0015
	Residual oil	1972-	78.0	0.0020	0.0030	0.0030
	Gas oil	1972-	74.0	0.0020	0.0015	0.0015
	Natural gas	1972-	56.9	0.0010	0.0040	0.0040
Industrial Combustion	Coal	1972-	95.0	0.0030	0.0150	0.0150
	Coke	1972-	105.0	0.0030	0.0150	0.0150
	Straw	1972-	0.0	0.0040	0.0320	0.0480
	Wood	1972-	0.0	0.0040	0.0320	0.0480
	Petroleum coke	1972-	92.4	0.0030	0.0015	0.0015
	Residual oil	1972-	78.0	0.0020	0.0030	0.0030
	Gas oil	1972-	74.0	0.0020	0.0015	0.0015
	LPG	1972-	65.0	0.0010	0.0009	0.0021
	Natural gas boilers	1972-	56.9	0.0010	0.0040	0.0040
Residential & Service Burners	Coke	1972-	105.0	0.0030	0.0150	0.0150
	Straw	1972-	0.0	0.0030	0.4000	0.6000
	Wood	1972-	0.0	0.0030	0.4000	0.6000
	Petroleum coke	1972-	92.4	0.0030	0.0015	0.0015
	Gas oil	1972-	74.0	0.0020	0.0070	0.0030
	Kerosine	1972-	72.0	0.0020	0.0070	0.0030
	LPG	1972-	65.0	0.0010	0.0009	0.0021
	Town gas	1972-	53.9	0.0010	0.0050	0.0050
	Natural gas boilers	1972-	56.9	0.0010	0.0050	0.0050

Sector	Fuel	Valid in period	CO2 kg/GJ	N2O kg/GJ	CH4 kg/GJ	NMVOC kg/GJ
Road transport	Diesel oil (Passenger car)	1972-85	74.0	0.0045	0.0031	0.0674
		1986-88		0.0044	0.0031	0.0673
		1989-90		0.0043	0.0029	0.0643
		1991		0.0045	0.0031	0.0643
		1992		0.0046	0.0031	0.0612
		1993		0.0046	0.0032	0.0615
		1994		0.0049	0.0032	0.0577
		1995		0.0049	0.0034	0.0559
		1996		0.0050	0.0035	0.0553
		1997		0.0051	0.0036	0.0499
		1998		0.0055	0.0035	0.0468
		1999		0.0055	0.0036	0.0434
		2005			0.0034	0.0254
		2010			0.0028	0.0210
		2015			0.0024	0.0181
		2020			0.0022	0.0164
		2025			0.0022	0.0161
		2030			0.0022	0.0159
	Diesel oil (light duty vehicle)	1972-85	74.0	0.0053	0.0021	0.0850
		1986-88		0.0053	0.0021	0.0847
		1989-90		0.0053	0.0020	0.0806
		1991		0.0053	0.0021	0.0829
		1992		0.0053	0.0021	0.0810
		1993		0.0053	0.0021	0.0832
		1994		0.0053	0.0021	0.0802
		1995		0.0052	0.0021	0.0797
		1996		0.0051	0.0021	0.0803
		1997		0.0051	0.0020	0.0767
		1998		0.0050	0.0020	0.0749
		1999		0.0049	0.0019	0.0689
		2005			0.0012	0.0632
		2010			0.0007	0.0443
		2015			0.0004	0.0294
		2020			0.0002	0.0207
		2025			0.0002	0.0173
		2030			0.0002	0.0168

Sector	Fuel	Valid in period	CO2 kg/GJ	N2O kg/GJ	CH4 kg/GJ	NMVOC kg/GJ
	Gasoline (road) &	1972-85	73.0	0.0019	0.0329	1.1784
	Gasoline(military)	1986-88		0.0019	0.0334	1.1647
		1989-90		0.0024	0.0328	1.1003
		1991		0.0036	0.0330	1.0397
		1992		0.0048	0.0319	0.9657
		1993		0.0058	0.0323	0.9115
		1994		0.0076	0.0310	0.8031
		1995		0.0089	0.0308	0.7286
		1996		0.0100	0.0311	0.6650
		1997		0.0119	0.0303	0.5469
		1998		0.0126	0.0298	0.4909
		1999		0.0137	0.0295	0.4175
		2005		0.0178	0.0206	0.2095
		2010		0.0187	0.0122	0.0842
		2015		0.0189	0.0080	0.0459
		2020		0.0191	0.0058	0.0328
		2025		0.0191	0.0052	0.0301
		2030		0.0191	0.0050	0.0290
	Biofuel	2005	0.0	0.0178	0.0206	0.2095
	Natural gas (road)	1972-	56.9	0.0020	0.0192	0.3585
	LPG (road)	1972-	65.0	0.0020	0.0192	0.3585
Other Mobile Sources	Residual oil (sea)	1972-	78.0	0.0049	0.0018	0.0569
	Diesel oil (off-road)	1972-96	74.0	0.0031	0.0045	0.1868
		1996-09				0.1854
		2010				0.1372
	Diesel oil (fishery)	1972-	74.0	0.0047	0.0017	0.0545
	Diesel oil (railway)	1972-	74.0	0.0020	0.0048	0.0432
	Diesel oil (sea)	1972-	74.0	0.0047	0.0017	0.0545
	LPG off-road	1972-	65.0	0.0031	0.0621	0.8385
	Gasoline off-road	1972-	73.0	0.0014	0.1024	5.0418
	Gasoline (air)	1972-	73.0	0.0019	0.0329	1.1784
	J.P.1 (air-LTO)	1972-94	72.0	0.0020	0.0044	0.0416
		1995			0.0045	0.0419
		1996			0.0034	0.0320
		1997			0.0034	0.0321
		1998			0.0034	0.0321
		1999-			0.0034	0.0321
Refineries	Refinery gas	1972-	56.9	0.0010	0.0040	0.0040
	Natural gas,turbine	1972-	56.9	0.0010	0.0185	0.0100
	Natural gas,flared	1972-	56.9	0.0005	0.0051	0.0026
	Residual oil	1972-	78.0	0.0020	0.0030	0.0030
International Transport	Residual oil (sea)	1972-	78.0	0.0049	0.0018	0.0569
	Diesel oil (sea)	1972-	74.0	0.0047	0.0017	0.0545
	J.P.1 (air-cruise)	1972-	72.0	0.0020	0.0028	0.0260

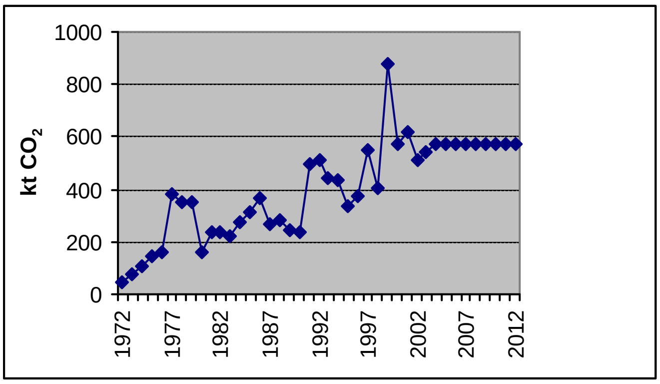
3.3 Fugitive emissions from fossil fuels

This section covers all emissions from production, processing, handling and transport of fossil fuels, which are not the result of combustion. For greenhouse gas emissions from Denmark this means emissions from the flaring of natural gas, CH_4 emissions from coal storage, CH_4 escaping from the gas networks, and CH_4 from refineries.

3.3.1 Flaring

The energy content of the natural gas flared is not included in the Danish energy balance. According to the Energy Agency the 0.8 PJ was flared in 1972 increasing to an expected maximum of 15.4 PJ in the year 2000, and thereafter decreasing to 10.0 PJ in 2010. The resulting CO_2 emission, following the same oil extraction curve, is shown in Figure 5. At the maximum in 1999 it is 0.88 Mt CO_2, falling to 0.57 Mt CO_2 in 2012. The CO_2 emission from flaring is not included in the Danish Energi21 target for 2005, but it is included in the United Nations Framework Convention on Climate Change and the Kyoto Protocol. In the IPCC guideline for Emission Inventories [36] the emissions from flaring is found in the category "fugitive emissions from fuels".

Figure 5. CO_2 emissions from flaring in the Danish North Sea



3.3.2 Refineries

In the production process at the refineries a part of the volatile hydrocarbons (VOC) is emitted to the atmosphere. It is assumed that CH_4 account for 1 % of the emission or 505g VOC/tonne of crude [7]. In table 10.5 the emissions are calculated to be only about 0.05 kt CH_4, based on the historic information and the projection for the processing of crude on Danish refineries. The calorific value used for crude oil is 42.7 GJ/t.

Table 9. Emissions CH_4 from refineries

	Crude oil processed (kton)	CH4 emission (kton)
kg CH4/t crude:		0.0051
1980	5187	0.03
1985	6558	0.03
1990	7871	0.04
1995	9809	0.05
2000	8345	0.04
2010	8199	0.04

3.3.3 Gas networks

The emission from leakage of CH_4 from the gas networks was estimated in the report "Danish Budget for Greenhouse Gases" [8] to be 7.9 kt CH_4 and from the town gas network in Copenhagen 0.6 kt CH_4. Thus the total CH_4 emission from gas networks were 8.5 kt CH_4. These values is being updated at the moment but since the work is not yet finished the result from [8] is therefore used here for the whole period.

3.3.4 Emissions from storage of coal in Denmark

As in [8,15] it is assumed that 50 % of the emissions under transport and storage are emitted in Denmark. As shown in Table 10 the CH_4 emission factors for coal and coal post mining is more than 20 times lower for surface mined coal than for underground mined coal [36]. In the calculation here the midpoint in this interval is used. It is therefore important to know the fraction of the coal imported by Denmark, which originates from underground mines. Table 11 shows the origin of the coal imported by Denmark. The table shows e.g. that the coal import from South Africa was stopped in the period 1987-1991. At the bottom of Table 11 the fraction of the coal mined underground in each country [14] is shown. Table 12 shows the time series of the total coal import and its disaggregation into surface and underground mined coal, based on the information in Table 11. It is assumed that the coal import in the future will originate from the same countries as it does in the last year covered by the statistics - 2001. The coal import is not corrected for electricity import/export.
The CH_4 emission had a maximum in 1997, where the emission was about 6.1 kt CH_4 falling to about 4 kt CH_4 in 2010 with some fluctuation over time.

Table 10. CH_4 emission factors for coal storage

	Underground kg CH_4/ton coal	Surface
Post mining	1.76	0.07
DK fraction	0.88	0.04

Table 11. Origin of the coal imported by Denmark (Unit: % of total import)

Import %	South Africa	Poland	USA	UK	Australia	Canada	USSR	Germany	Colombia	Russia	Other
1980	31.2	34.2	13.8	5.9	4.9	2.0	3.9	2.7			1.4
1981	28.9	5.4	39.3	17.8	2.6	4.6	0.8				0.6
1982	32.6	9.6	29.9	21.2	1.3	3.5	1.4	0.1			0.4
1983	34.5	14.2	18.1	19.5	5.1	3.4	4.4	0.1			0.7
1984	28.3	32.4	7.1	5.9	18.3	4.5	1.9	0.1			1.5
1985	27.9	15.2	18.1	10.4	19.8	2.6	2.0	0.1	2.7		1.2
1986	22.1	12.0	16.9	8.8	21.3	2.4	5.1		10.0		1.4
1987		15.9	9.1	9.6	33.0	2.5	6.5		20.4		3.0
1988		13.1	29.8	5.0	13.4	2.1	8.0		22.3		6.3
1989		7.2	29.1	4.9	15.1	5.5	7.4	0.0	23.3		7.5
1990		8.6	32.9	6.0	11.5	6.6	11.6	0.0	21.2		1.6
1991		4.8	37.6	1.3	15.4	5.2	11.8	0.0	21.0		2.9
1992	3.2	8.2	30.9	1.0	13.7	10.4	3.3	0.3	16.6	7.6	4.8
1993	31.7	19.7	4.5	0.3	6.3	2.2		0.0	14.5	17.3	3.5
1994	25.5	32.5	5.4	1.0	9.0	2.7		0.0	11.6	8.1	4.2
1995	26.3	27.2	20.0	0.0	4.9	0.4		0.0	8.6	8.5	4.1
1996	38.8	20.7	12.1	0.1	6.0	0.0		0.0	16.9	3.6	1.8
1997	33.0	25.1	2.3	0.0	10.3	1.4		0.0	19.8	3.1	5.0
1998	35.9	31.6	6.9	0.0	5.4	0.0		0.3	16.7	2.6	0.6
1999	25.7	35.7	0.0	0.0	7.1	0.0		0.0	17.7	11.9	1.9
2000	26.0	33.8	1.1	0.0	2.2	0.0		0.0	12.6	20.5	3.8
2001	26.1	29.9	0.8	0.0	2.3	0.0		0.1	6.0	26.5	8.5
Underground fraction											
	0.64	0.73	0.41	0.84	0.25	0.06	0.56	0.18	0.00	0.56	0.55

Table 12. Total coal import and the resulting emissions of CH_4

	Import in mio. tons			CH_4 emission (kt)
	Total	Underground	Surface	
1980	10.01	6.03	3.98	5.45
1981	10.72	5.93	4.79	5.39
1982	9.51	5.67	3.84	5.12
1983	8.38	5.08	3.30	4.59
1984	9.67	5.45	4.23	4.94
1985	12.54	6.53	6.02	5.96
1986	12.03	5.58	6.45	5.14
1987	11.91	4.42	7.49	4.16
1988	9.14	3.42	5.72	3.22
1989	10.50	3.55	6.95	3.37
1990	9.81	3.48	6.32	3.29
1991	12.50	4.06	8.44	3.87
1992	12.06	4.15	7.90	3.94
1993	10.34	5.17	5.17	4.74
1994	11.71	6.12	5.59	5.58
1995	12.90	6.85	6.05	6.24
1996	12.43	6.15	6.28	5.63
1997	14.00	6.65	7.36	6.11
1998	8.31	4.32	3.99	3.94
1999	7.01	3.64	3.38	3.32
2000	6.42	3.58	2.84	3.25
2001	6.95	4.09	2.87	3.70
2002	6.97	4.11	2.88	3.72
2003	6.83	4.02	2.82	3.64
2004	6.62	3.90	2.73	3.52
2005	7.39	4.35	3.05	3.93
2006	7.64	4.50	3.16	4.07
2007	8.37	4.93	3.46	4.46
2008	8.53	5.02	3.52	4.54
2009	8.67	5.11	3.58	4.62
2010	8.85	5.21	3.66	4.72
2011	8.94	5.27	3.70	4.76
2012	9.01	5.31	3.73	4.80

4 Industrial Processes

Greenhouse gases are produced from a variety of industrial activities, which are not related to energy. This section covers the emissions from industrial production processes, which chemically or physically transform materials. For Denmark this means CO_2 emissions from the production of cement, lime and yellow bricks, and emissions of HFCs, PFCs and SF_6.

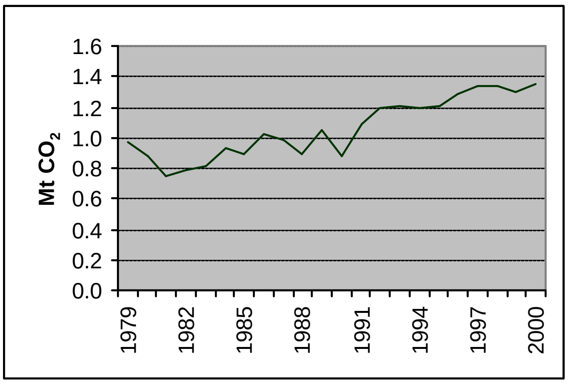
4.1 Mineral Products

4.1.1 Cement, lime and yellow bricks production

Only the mineral products sector is contributing to the emission of CO_2. In 2000 a total of 1.46 million tonnes of CO_2 originated from production of cement, lime and yellow bricks. According to Table 3 this is an increase of about 50% from the 1.0 $MtCO_2$ in 1990. However, the present level of emissions are not expected to increase in the period until 2012.

The CO_2 emissions from cement production are shown in Figure 6. In 2000 the emission was 1.35 million tonnes of CO_2. Since 1990 the emission has been increasing due to the increase in building activity. The Ålborg Portland plant is now running at its full capacity, it is therefore assumed that the Danish CO_2 emission form cement production will not increase in the period to 2010, since it will take 5-10 years for a new cement plant to be operational after the decision to build it.

Figure 6. CO_2 emission from cement production



The curve in Figure 6 is based on information from Ålborg Portland [17]. The total CO_2 emissions in the figure consist of two parts: The emissions from white cement calculated the amount of white cement produced multiplied by an emission factor of 0.669 t CO_2/t cement. The CO_2 emission from grey cement is calculated as the amount of grey cement weighted by the relative fractions of the three types of clinker multiplied by the three respective emission factors shown in Table 13 [17].

Table 13. CO_2 emission factors for grey cement

	t CO_2/t grey cement
Low alkali cement (SKL/RKL clinker)	0.610
Rapid cement (GKL clinker)	0.477
Basis cement (FKH clinker)	0.459

The source of information for the production of bricks and lime is the Industrial Sales Statistics [18]. Assuming that half of the bricks are yellow bricks, their production gives rise to an emission of 0.158 kg CO_2/brick [19]. This emission factor is calculated the following way. When limestone ($CaCO_3$) is heated it decomposes into lime (CaO) and CO_2. Using the molecular weights, 44 kg of CO_2 is emitted for every 100 kg $CaCO_3$ decomposed. Since clay used to produce yellow bricks contains 18% limestone and the average weight of a brick is 2 kg, the emission factor is 2*0.18*0.44= 0.158. With the annual production of yellow bricks shown in Table 14, the emissions from brick production was in the range 0.02-0.03 million tonnes of CO_2 in the period 1988-2000.
If the amount of yellow bricks used in Denmark is projected with the long range annual increase of 1.5% p.a. used in the ADAM projections for the supplier of building materials made by Denmark's Statistics, the CO_2 emissions from yellow bricks will increase to 0.04 Mt CO_2 in 2010.

Table 14. CO_2 emissions from production of yellow bricks

Year	Yellow brick production Million bricks	CO_2 emission 1000 tonnes
1988	173	27
1989	170	27
1990	146	23
1991	146	23
1992	151	24
1993	139	22
1994	195	30
1995	183	29
1996	199	31
1997	210	33
1998	212	33
1999	202	32
2000	206	33

The production of lime emits 0.785 t CO_2/t burned lime (standard IPCC value), since 44.01 kg of CO_2 is emitted for every 56.08 kg of CaO produced, according to the molecular weights in the two products in the disintegration of $CaCO_3$. According to Table 15 the annual emission from lime production was in the range 0.07-0.10 million tonnes of CO_2 in the period 1988-2000.

Table 15. CO_2 emissions from production of burned lime.

Year	Burned lime prod. 1000 tonnes	CO_2 emissions 1000 tonnes
1988	115	90
1989	102	80
1990	127	100
1991	86	68
1992	105	82
1993	107	84
1994	112	88
1995	101	79
1996	95	75
1997	103	81
1998	89	70
1999	95	75
2000	92	72

4.1.2 HFCs, PFCs and SF_6

This section contains a projection of the emissions of three groups of greenhouse gases, perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and hydrofluorocarbons (HFCs) through to the year 2020. These gases were added to the gases CO_2, CH_4 and N_2O under the 1997 Kyoto Protocol to the United Nations Framework Convention on Climate Change. The GWPs of the gases are shown in Table 1.

The information in Table 16 is from a report made by COWIconsult [20]. The emission levels have decreased compared to former reports for several reasons:

1) Because the actual emissions have been corrected for the greenhouse gases contained in the exported and imported appliances.

2) A tax has been introduced on these three groups of gases amounting to $1/10^{th}$ of their GWP in Table 1 up to a maximum of 400 kr/kg.

3) New Danish legislation containing dates for outphasing import, production and use of these industrial greenhouse gasses.

4) New rules for decommissioning, where the GHG in refrigerators, foam etc. are destroyed instead of emitted to the atmosphere. This is a mayor reason for the decrease in the present projection compared to the last one in [58]. The difference with the old calculation is especially large in the second commitment period, 2013-17 (marked as "2015").

5) Further there have been changes in the leak-rates for commercial and mobile refrigerants. The reduction in leak-rates decreases the emission form those sources with a smaller amount.

In agreement with Article 3.8 of the Kyoto Protocol, the Denmark has chosen 1995 as the base year for HFCs, PFCs and SF_6 [57]. The total emission of the three groups of gases increase from 0.35 Mt CO_2 in 1995 to the peak of 0.81 Mt CO_2 in 2000. Thereafter the emission decrease gradually to 0.71 Mt CO_2 in "2010" and further to 0.50 Mt CO_2 in "2015".

The emissions are calculated using the IPCC method for actual emission, taking into account the time lag between consumption and emission, which may be considerable in some application areas, e.g. closed cell foams and refrigeration.

Hydrofluorocarbons (HFCs)

HFCs are used as replacements for chloro-fluorocarbons (CFCs) and hydrochloro-fluorocarbons (HCFCs). Unlike the CFCs and the HCFCs, HFCs do not convey chlorine to the stratosphere and thus do not contribute to ozone depletion. According to the 1987 Montreal Protocol and its subsequent amendments, CFCs were largely banned for developed countries after January 1996 (and developing countries after 2010), although some countries have failed to meet the deadline. Furthermore, according to global rules, HCFC usage will be subject to a gradual phase-out with cuts of 35%, 65% and 90% in 2004, 2010 and 2015, respectively. Final HCFC consumption phase-out will occur in 2020 (2040 for developing countries). The main sources of emissions of HFCs are from the uses as refrigerant in cooling and as a blowing agent for insulation foams. The most used HFC is HFC-134a. The mixtures with the names R-401a to R-507a contains various amounts of different HFCs sometimes mixed with HCFCs and hydrocarbons. The weight in tonnes of the emissions of these R-mixtures are therefore not only HFCs. However, in order to calculate the total emissions in CO_2 equivalents, the GWPs shown at the top of the table were used. The GWPs

for the mixtures are calculated from the GWP of the individual HFCs in the mixture.
The main emission is from HFC-134a and HFC-404a (containing 44% HFC-125, 4% HFC-134a and 52% HFC-143a). The total emission reaches 0.64 Mt CO_2 in "2010" and only 0.37 Mt CO_2 in "2015".

Perfluorocarbons (PFCs)
PFCs are fully fluorinated hydrocarbons. Because of their extreme long atmospheric lifetimes (2,600 - 50,000 years), they have particularly high GWPs.
The production of aluminum is thought to be the largest source of emissions of the CF_4 and C_2F_6. These emissions are produced primary by the anode effect, which occurs during the reduction of alumina (aluminum oxide) in the primary smelting process, when alumina concentrations become too low in the smelter. Under these conditions, the electrolysis cell voltage increases sharply to a level sufficient for bath electrolysis to replace alumina electrolysis. This causes a high energy loss and a release of fluorine, which combines with the carbon to form CF_4 as well as C_2F_6 in lower quantities. However, there is no primary aluminum production in Denmark. The only source of PFC emission is the use of a small amount of Perflouropropane (C_3F_8) as a component in a cooling liquid in some older cooling installations. Table 1 shows that the emission of PFC (C_3F_8) from Denmark had a maximum of 28 kt CO_2-eq. in 2000 and decreases to 18 kt CO_2 -eq. in "2010" .

Sulphur hexafluoride (SF_6)
Sulphur hexafluoride is an extremely stable atmospheric trace gas. Its unique physico-chemical properties make this gas ideally suited for many specialised industrial applications. Its GWP of 23,900 is the highest of any atmospheric trace gas.
The emissions of SF_6 from Denmark are from three main applications. The largest consumer (60%) is the glass industry, using SF_6 as a sound insulating gas. The second largest consumer is the power plants using SF_6 as an electrical insulation gas. Additionally there is a small consumption (6%) in magnesium foundries, where SF_6 is used to prevent oxidation of molten magnesium and laboratories using the gas.
The time-serie for the emission on SF_6 in Table 16 declines from 107 kt CO_2-eq. in 1995 to 28 kt CO_2 -eq. in 2008 but increases to 107 kt CO_2-eq. in 2012 due to end of life emissions.

Table 16. Actual emission of HFCs, PFCs and SF_6 from Denmark

kt CO2-eq.	HFC-	HFC-	R-401a	R-402a	R-404a	R-407c	Other	R-507a	HFCs	SF6	PFCs	Total
actual	134a	152a					(R-410a)		Total			
GWP	1300	140	18.2	1680	3260	1526	1725	3300		23900	7000	
1993	91.5	4.2	0.0	0.0	0.0	0.0	0.0	0.0	95.7	134.6	0.0	230.3
1994	131.6	6.4	0.0	0.3	2.9	0.0	0.0	0.0	141.1	122.1	0.1	263.4
1995	200.9	6.1	0.0	2.2	26.9	0.0	0.8	0.0	236.9	107.3	0.9	345.1
1996	271.6	4.5	0.0	6.4	88.2	0.0	5.2	0.0	375.9	61.0	2.9	439.8
1997	244.5	2.1	0.0	10.8	132.2	0.7	9.9	0.9	401.2	73.1	7.2	481.5
1998	295.1	1.3	0.1	11.7	171.7	4.4	12.9	5.2	502.3	59.4	15.0	576.7
1999	330.8	5.3	0.1	12.8	231.4	9.3	15.9	9.5	615.1	65.4	19.8	700.4
2000	353.6	2.3	0.1	13.4	306.4	18.3	21.4	14.7	730.1	59.2	28.3	817.7
2001	336.1	1.8	0.1	7.7	266.7	15.3	27.0	13.1	667.7	30.4	17.6	715.7
2002	360.3	1.7	0.1	6.4	273.9	19.9	28.4	12.5	703.1	29.1	19.1	751.3
2003	368.9	1.6	0.1	5.7	281.6	24.1	29.4	11.9	723.2	28.8	17.8	769.8
2004	381.9	1.6	0.1	4.7	287.8	27.8	30.1	11.4	745.5	27.2	17.3	790.0
2005	394.5	1.6	0.1	3.9	291.0	30.9	30.9	10.7	763.6	27.4	17.2	808.2
2006	339.7	0.1	0.1	3.5	296.5	33.7	18.8	9.9	702.2	27.6	17.3	747.1
2007	342.5	0.1	0.0	3.0	302.8	34.9	18.7	9.2	711.3	27.8	17.2	756.4
2008	342.5	0.1	0.0	2.6	304.2	30.6	16.4	7.4	703.9	28.1	17.3	749.2
2009	329.8	0.1	0.0	2.3	301.4	26.9	14.4	6.6	681.6	28.3	17.6	727.4
2010	317.6	0.1	0.0	2.1	294.0	23.5	12.7	5.9	655.8	28.5	17.8	702.1
2011	308.5	0.0	0.0	1.9	258.3	20.4	11.1	5.2	605.5	60.8	18.0	684.4
2012	278.0	0.0	0.0	1.6	230.0	17.7	9.7	4.6	541.7	106.9	18.2	666.8
2013	264.0	0.0	0.0	1.5	206.1	15.2	8.4	4.1	499.3	116.9	18.4	634.5
2014	221.0	0.0	0.0	1.3	182.3	13.0	7.2	3.6	428.5	129.4	18.6	576.4
2015	199.6	0.0	0.0	1.2	151.2	11.7	6.5	3.2	373.5	114.7	18.7	506.9
2016	173.0	0.0	0.0	1.0	114.1	10.5	5.9	2.9	307.5	87.0	18.8	413.3
2017	156.5	0.0	0.0	0.9	87.3	9.5	5.3	2.6	262.2	72.1	18.9	353.2
2018	141.5	0.0	0.0	0.8	65.0	8.5	4.7	2.4	223.1	102.0	19.1	344.2
2019	127.8	0.0	0.0	0.8	46.5	7.7	4.3	2.1	189.2	71.3	19.1	279.6
2020	115.0	0.0	0.0	0.7	31.3	6.9	3.8	1.9	159.6	50.8	19.2	229.7

5 Agriculture

The emission calculations in this section was done together with a working group with participants from, the Ministry of Food, Agriculture and Fisheries, Danish Institute of Agriculture and Fisheries Economics, Danish Institute of Agricultural Sciences and the National Environmental Research Institute, as reported in [47,48].

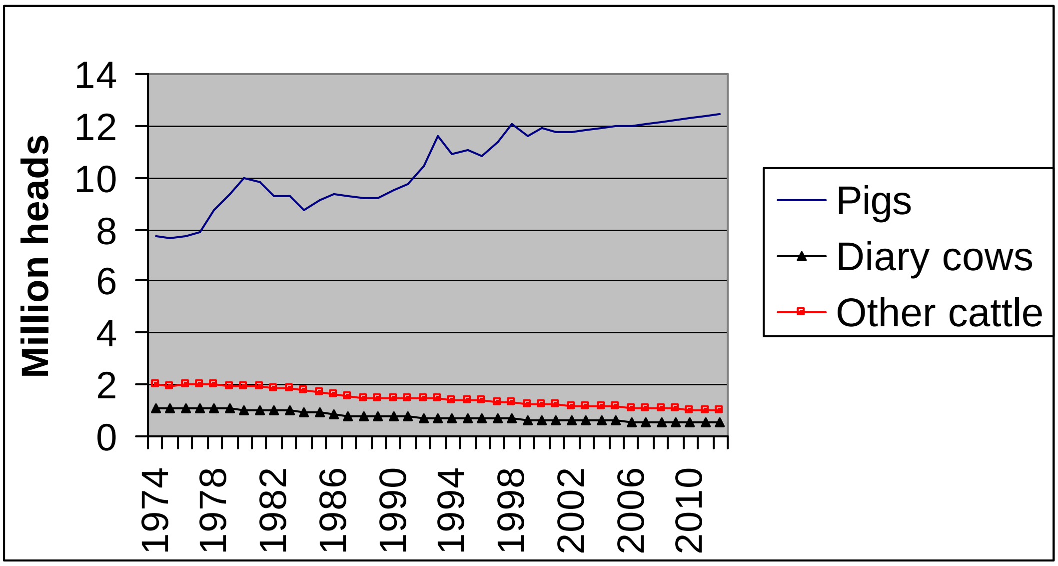
5.1 CH_4 from Enteric Fermentation & Manure Management

Methane is produced as a by-product during the digestive processes in animals. All domestic animals emit CH_4, but the largest contribution comes from ruminants, due to their ability to breakdown cellulose. The number of domestic livestock in Denmark is shown in Table 17 and
Figure 7. The data sources are the Danish ten-year statistical review [21] for all the types of domestic animals except for dairy cows, and turkey-ducks-geese, which are taken from a series of Danish annual statistics [22]. In the Second Communication to the UNFCCC [1] cows kept for suckling were included in "dairy cows". They are now included in "other cattle", since they have an emission factor similar to that category. Fur animals are not included since no emissions factors exist for this category. The number of cows is assumed to decrease 1.8% per year [46]. The amount of pigs slaughtered annually is assumed to increase 1.5% p.a. from 2000 until 2012; this number is then driving the future amount of sows [46]. As shown below, the total emissions in 2000 of CH_4 from agriculture was 170.3 kt, consisting of 134.2 kt from enteric fermentation and 36.1 kt from manure management.

Table 17. Domestic livestock in Denmark

1000 heads	Horses	Dairy cows	Other cattle	Sows	Other Pigs	Sheep's	Slaughter chickens	Other fowls	Turkeys,ducks & Geese
1974	55	1110	1990	909	6854	59	7131	8286	1000
1975	58	1094	1966	875	6807	61	7174	8088	1000
1976	60	1106	1989	904	6797	59	8088	6685	1000
1977	61	1099	2000	910	7015	56	8398	6545	1000
1978	59	1091	1990	995	7756	56	8050	6714	1000
1979	56	1071	1964	1045	8297	54	8401	6615	1000
1980	50	1039	1922	1071	8886	56	7533	6710	1266
1981	44	1016	1898	966	8833	55	8611	6728	1000
1982	41	999	1874	953	8366	58	8608	6577	1000
1983	33	1003	1849	922	8331	52	8304	6462	1418
1984	33	951	1799	893	7824	55	8694	5721	1084
1985	32	896	1722	928	8161	70	8490	5577	1152
1986	30	864	1631	949	8372	89	8420	5588	1212
1987	33	811	1540	923	8343	101	9602	5017	831
1988	34	774	1488	901	8316	124	9332	5436	756
1989	35	759	1462	883	8307	144	10860	5406	928
1990	38	753	1486	904	8593	159	9802	5696	751
1991	32	742	1480	928	8855	188	10019	5067	846
1992	28	712	1478	1001	9454	182	12620	5639	782
1993	20	714	1481	1041	10527	157	13399	5517	982
1994	18	700	1405	992	9931	145	12023	6931	897
1995	18	702	1388	1015	10069	145	12585	6088	946
1996	20	701	1392	1010	9832	170	12907	6317	663
1997	39	670	1334	1068	10315	142	12510	5646	838
1998	40	669	1308	1092	11003	156	13118	4905	650
1999	40	640	1247	1061	10566	143	14923	5045	1042
2000	40	636	1232	1083	10838	145	16047	4935	849
2005	40	580	1125	1031	10926	145	16047	4935	849
2010	40	530	1028	1023	11295	145	16047	4935	849
2012	40	511	991	1022	11461	145	16047	4935	849

Figure 7. Development of the main livestock categories



5.1.1 CH_4 emissions from enteric fermentation

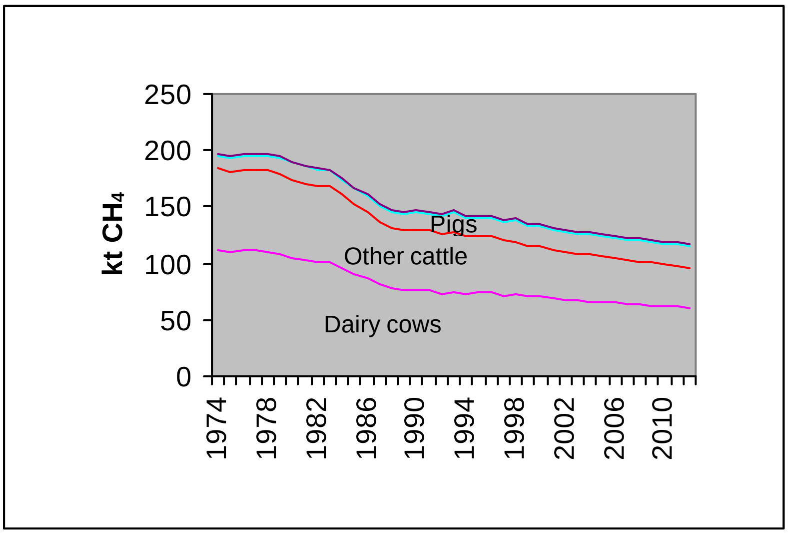
IPCC gives two alternative ways to estimate CH_4 emissions. Tier 1, which just uses the IPCC default emission factors for the region, and Tier 2, in which emission factors are calculated based on local conditions. The CH_4 emission per animal is here calculated based on weight, weight gain, frequency of pregnancy, fat % of the milk, and the energy efficiency of the animal. In the Second Danish Communication [1], Tier 1 was used for all animal categories. However, due to new information [23], Tier 2 is now used for cattle, which by far is the largest CH_4 emitter from enteric fermentation.
Table 18 shows that the emission factor for dairy cows in Tier 2 is expected to increase from the present 101 kg CH_4/yr/head to 119 kg CH_4/yr/head in 2012 [23], due to the expected higher productivity per head..

Table 18. CH_4 emission factors for enteric fermentation

Kg CH_4/yr per head	Horses	Dairy Cows	Other cattle	Sows	Other pigs	Sheep
Tier 1	18.0			1.5	1.5	8.0
Tier 2, 1974-89		101.0	37.0			
Tier 2, 1999		110.0	37.0			
Tier 2, 2003		111.0	37.0			
Tier 2, 2012		119.0	37.0			

Figure 8 shows that the CH_4 emission has been decreasing from about 200 kt in the seventies to 134 kt in 2000 due to the decreasing number of cattle. Since the enteric emission factor for pigs are much lower, the increasing number of pigs only result in a small increase in the emissions. Emissions for chickens, fowls and fur animals are not included since no emission factors are available. The emissions in 2000 from horses (0.7 kt) and sheep (1.2 kt) are too small to be seen on Figure 8. The above-mentioned decrease in the number of cattle outweighs the increase in the emission factor for cattle and the increase in the number of pigs.

Figure 8. CH_4 emissions from enteric fermentation in domestic livestock



5.1.2 CH_4 emissions from manure management

Two changes have been made in the present emission calculations for CH_4 from manure management compare to the one presented in the Second

Danish Communication [1], where Tier 1 was used for all animal categories. Based on the information in [23], Tier 2 is now used for all animal categories. The second change is that the emission factors for a cool climate, having an average temperature below 15 degrees, are now used (see definition in the IPCC Revised Guidelines [36], footnote to table 4-6). In the Second Danish Communication [1] the Tier 1 emission factors for temperate climate, with average annual temperatures in the range 15-25 degrees were used.
The resulting total CH_4 emissions from manure management are very sensitive to which set of emission factors that are use for Denmark. Figure 9 shows that the total CH_4 emission decreases from 38,6 kt CH_4 in 2000 to 36.5 kt. CH_4 in 2012.

Table 19. CH_4 emission factors for manure management.

kg CH4/yr	Horses	Dairy cows	Other cattle	Sows	Other pigs	Sheep	Slaughter chickens	Other fowls	Turkeys, ducks & geese
Tier 2 cool	1.1	19.9	1.5	4.7	1.7	0.4	0.02	0.07	0.05

The Tier 2 CH_4 emission factors for "other cattle", "other pigs", "other fowls", and "Turkeys-ducks-geese" are weighted averages of emission factors calculated in [23].

Figure 9. CH_4 emissions from manure management (excl. biogas plants).

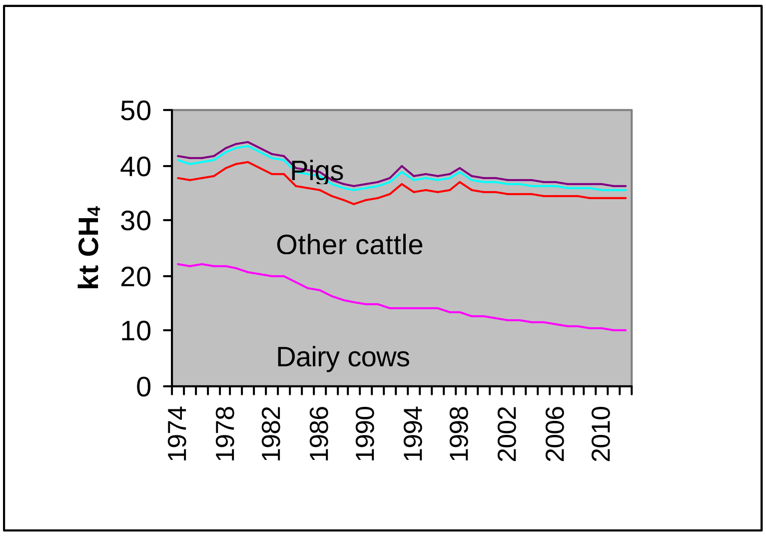
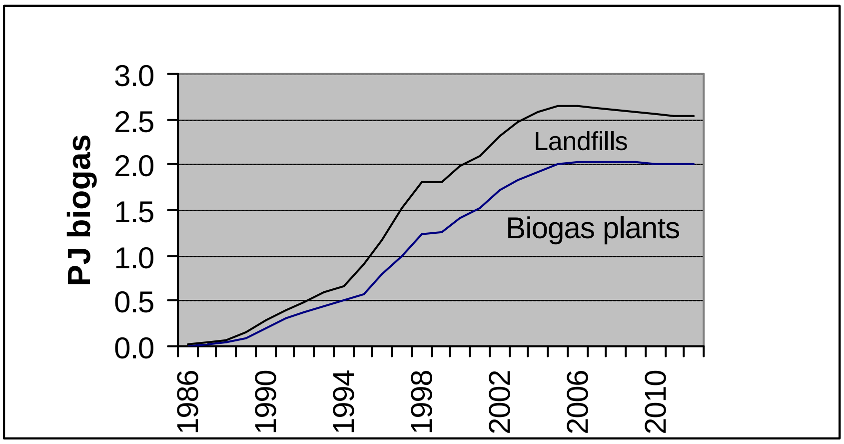


Figure 9 shows that the CH_4 emission has been decreasing from about 42 kt in the seventies to 38,6 kt in 2000. The increase in the emission from the manure from the increasing number of pigs has almost balanced the drop due to the decreasing number of dairy cattle. The total CH_4 emission from horses, sheep and fowls is so small (0.8 kt) that it is almost impossible to see it on Figure 9. The CH_4 emission projection for manure management is based on the animal projection in Table 17 and the emission factors in Table 19.

However, the emissions shown on Figure 9 are not the actual emissions of CH_4 from manure management. The reductions caused by the biogas plants have to be subtracted. The production of biogas at sewage gas plants, industrial biogas plants and landfill biogas plants is subtracted from the total production of biogas according to the Danish Energy Agency. The rest is then the production at agricultural biogas plants as shown in Figure 10. The main part of the production is on joint biogas plants the rest on smaller plants on single farms. Of the total production in 2000 of 2.92 PJ, 0.58 came from landfill gas plants, 0.86 PJ from sewage gas plants, 0,07 from industrial biogas plants. From agricultural biogas plants the production was therefore 1.42 PJ. The data before 1995 is from [29] combined with information from landfill biogas production. The production from agricultural biogas plants is expected to increase 46% from the 1.4 PJ in 2000 to around 2 PJ in 2004. The production values are from [28], which however is lower than the former projection in the Danish Energy Plan "Energi21". There is thus not included any new biogas plants after 2004 in the projection.

Figure 10. Total biogas production



Assuming a calorific value for biogas of 24 MJ/m^3 biogas, a content of 60% CH_4 in biogas [29], a CH_4 density of 0.72 kg/ m^3, the 2000 production e.g. equals 25.5 kt CH_4. However, the emissions of 38.6 kt CH_4 from manure management in 2000 shown on Figure 9 are not reduced by this value but only with 9.7% of 22.5 or 2.5 kt CH_4. This is because the manure produces much more CH_4 in a biogas plant than under normal storage conditions. The 9.7 % were calculated based on the new information in [63], where the reduction in CH_4 emission from biogas plants has been calculated. If 1 kg average volatile solid (VS) containing 30% cattle manure, 26% pig manure and 44% industrial organic waste is processed in a biogas plant it will produce 0.314 m^3 CH_4. Combining this with the information in the report [63] that the emission reduction by the treatment of 1 kg VS is 0.0218 kg CH_4 = 0.030 m^3 CH_4 the result is a reduction of 9.7%. With the projected biogas production in Figure 10, the emission of 36.5 kt CH_4 in 2012 on Figure 9 will be reduced by 3.5 kt CH_4 to 33.0 kt CH_4.

5.2 N_2O from agriculture

Production of N_2O in soils is a result of nitrification (an aerobic microbial oxidation of ammonium to nitrate) and denitrification (an anaerobic microbial reduction of nitrate to nitrogen gas). Nitrous oxide (N_2O) is a gaseous intermediate in the reaction sequence of both processes. Formation of N_2O is enhanced by an increase of available nitrogen. Only anthropogenic emissions are included, defined as emissions from cultivated land. Emissions from unfertilised fields are considered as background emission.

The total N_2O emission in 2000 from Danish agriculture was 27.3 kt N_2O expected to decrease to 24.3 kt N_2O in 2010 (see Table 21, part 2). The N_2O emissions were calculated for the sources listed in Table 20 by multiplying the emission factors with the respective activity data for the N-inputs after subtraction of the NH_3 evaporation (except for manure management, where the emission factor is use before subtraction of evaporation). The emission factors are the IPCC default values [36].

Table 20. N_2O emission factors for agriculture

	kg N_2O-N per kg N input	Emission in 2000 kt N_2O
Synthetic fertilisers	1.25%	4.72
Animal fertilisers	1.25%	3.54
N-fixation	1.25%	0.80
Atmospheric N deposition	1.00%	1.32
Industrial waste fertilisers	1.25%	0.10
Sewage sludge fertilisers	1.25%	0.07
Crop residues	1.25%	6.22
Liquid manure management	0.1%	0.26
Solid manure management	2.0%	2.08
Reduction by biogas plants		-0.04
Animal grazing	2.0%	0.91
Nitrogen leaching & runoff	2.5%	7.19
	Kg N_2O-N/ha	
Histosols	5	0.14
Total		27.31

Table 20 shows that the largest N_2O emissions originates from Nitrogen leaching & runoff (7.2) and from crop residues (6.2 kt). The third largest source is the synthetic fertilisers (4.7 kt). As a new thing a line has been introduced to account for the reduction of N_2O due to the treatment of manure at biogas plants, the emission reduction increases from 0.01 kt N_2O in 1990 to 0.05 kt N_2O in 2010. This reduction is based on the projection for biogas production in section 5.1.2., using the information in [63] that if 1 kg of the average volatile solid (VS) is treated in a biogas plants it will produce 0.314 m^3 CH_4 and will reduce emission by 0.325 kg N_2O from the manure. Combining this with the information in section 5.1.2 of the total biogas production gives the N_2O emission reduction mentioned.

Table 20 do not include the emission of 0.11 kt N_2O from the use of 5.8 kt N in synthetic fertilisers used on parks and lawns.

Table 21 (part 1 and part 2) shows how these N_2O emissions from the above-mentioned sources were calculated for the period 1985-2010. The source of the synthetic fertiliser user is [53]. Here the 1997/98 value is used for 1998 and the 5.8 kt N in synthetic fertilisers used on parks and lawns subtracted. According to table 4.12 in the midterm evaluation of “Vandmiljøplan II” a reduction in synthetic fertiliser use of 19.7 kt N had been reached in 1999 of goals in the plan and 59.8 kt plus 13.5 (Agenda 2000) is expected to be reached in 2003. The 2003 value for fertiliser used in the projection is therefore the 1999 value of 256.9 kt minus the extra 53.5 to be reached in the period 1999-2003 plus the impact of the extra initiatives in the Danish government’s plans for “Vandmiljøplan II” [51] and NH_3 emission reductions [52]. These initiatives are expected to reduce the use of synthetic fertiliser with 24.3 kt before 2003. The value for 2003 is therefore 179.1 kt N. Before the N_2O emission is calculated by multiplying with the emission factor of 1.25% from Table 20, the N content of NH_3 emission in Table 21, part 3 from the fertiliser use (close to 2%) is subtracted.

Concerning animal manure, the historical data is from [25] (1998/99 values are used for 1999 etc.) and the future data for 2003 and 2010 are from [26], this historical report [25] contain information for the years 1984, 1989, 1995, 1996, 1997, 1998 and 1999. Linear interpolation is used for the years in-between. For the years in-between values are interpolated linearly. In the column in Table 21, part 1 showing N-input from animal grazing, the NH_3 emission shown in Table 21, part 3 is subtracted. The values in Table 21, part 1 for N-input from animal fertiliser on soils is also after subtraction of NH_3 evaporation. However the N content in manure management in Table 21, part 3 is according to the IPCC rules before any NH_3 evaporation has taken place. The fractions of the total amount of manure, which are solid (21.5%) and liquid (71.5%) [24] are kept constant in the time series.

The N-input from nitrogen fixation in Table 21, part 2 is lower than in former inventories, because now only the symbiotic N-fixation is included (about 90% of the total N-fixation). The data is from Appendix A in [26], where 1998/99 data is used for 1999 and also for all future years.

The activity data for the historic N-inputs from industrial waste and sewage sludge used as fertilisers are from the field-N-balance appendix 3.1 in [27]. The future N-input from industrial waste has been put equal to the 1999 value. According to [23] the N-input from sewage sludge is expected to decrease in the period 1999-2003.

The combined action of "Vandmiljøplan I" (called The Action Plan on the Aquatic Environment), the Danish Action Plan for Sustainable Agriculture and the "Vandmiljøplan II" was expected to result in a decrease in the N-input from leaching & runoff (="udvaskning") from 230 mill. kg to 130 mill. kg in 2003. With the new initiatives in the Governments plan after the midterm evaluation of “Vandmiljøplan II”[51] the 100 mill. kg N reduction in the leaching & runoff is expected to be reached in 2003. However, one of the initiatives in this plan is to speed up the increase in the wetland area in such a way that it will absorb 3.6 kt N in 2003. This is the reason for the expected 2003 value in Table 21, part 2 for leaching & runoff to be 133.6 kt N instead of 130.0 kt N. No change is expected after 2003.

The IPCC method [36] for the calculation of N_2O emissions from crop residues was used in the calculations. Here it is assumed that the amount of Nitrogen in the crop residues is equal to the N-content in the crops. The values in the “N- in crops” column in Table 21, part 2 is from the appendices in [25], except that the historical amounts of cereal straw and rape/pea straw has been subtracted and shown in two separate columns. The amount of rape/pea straw is from [54] and has an N-content of 1%, the double of the N-content in cereal straw. The values for cereal straw are from [25]. The future projection for the N-content in cereal straw is expected to be proportional to the increase in the amount of straw used in the energy sector. According to the midterm evaluation of “Vandmiljøplan II” the N-content in catch crops will increase to 3 kt N in 2003.

The total area in Denmark covered with histosols, defined as colour-code 7/JB 11 in the Danish soil classification, is 237,700 ha. Histosols are cultivated organic soils originating from old N-rich organic matter. However, only 184,400 ha are used for agricultural purposes. Of this area again 90% is used for grassland, which is in a stable situation, without N_2O emissions. This means that only 10%, or 18,400 ha of histosols area [23] is included in Table 21, with an annual emission of 0.14 kt N_2O using the emission factor of 5 kg N_2O-N/ha shown in Table 20. When these soils are cultivated, their surface gradually sinks. However, emission of CO_2 from this process in histosols has not been included.

The only source of N_2O in Table 21 not yet mentioned is the N_2O release after deposition of NH_3. According to Table 20 an emission factor of 1% should be used for the NH_3 deposited in Denmark. However, IPCC recommend that the deposition = evaporation of NH_3 - N from Denmark (import/export are not taken into account). Time series for all the sources of NH_3 emission are shown in Table 21, part 3. These data for NH_3 from synthetic fertiliser, animal manure, straw leaching and evaporation from sludge is from the new projection of NH_3 emissions to be published in [64]. Here the emission of NH_3 has increased primary due to a change in the estimation of the way the manure is being spread on the fields. There exist no statistics on the practice used by the farmers and an estimate has to be used. The total evaporation from agriculture in e.g. 2010 has with this change increased from 61.2 kt NH_3-N to 75.6 kt NH_3-N and thereby increasing the N_2O emission by 0.2 kt N_2O.
The NH_3 emission from straw leaching is expected to drop to zero in 2003 according to the expected ban on this activity [52].

Table 21. N-input and N_2O emissions from agriculture

Part1	Synthetic fertiliser		Animal grazing		Animal fertilisers on soils		Manure management (before evaporation)			
	N-input (mill.kg N)	N2O emission (kt N_2O)	N-input (mill.kg N)	N_2O emission (kt N_2O)	N-input (mill.kg N)	N_2O emission (kt N_2O)	Solid	Liquid (mill.kg N)	Total	N_2O emission (kt N_2O)
1985	392.3	7.55	31.9	1.00	192.7	3.78	80.1	200.9	281.0	2.83
1986	376.3	7.25	31.4	0.99	189.9	3.73	79.2	198.7	277.9	2.80
1987	375.5	7.23	30.8	0.97	187.0	3.67	78.3	196.4	274.7	2.77
1988	361.2	6.96	30.3	0.95	184.2	3.62	77.4	194.2	271.6	2.74
1989	371.2	7.15	29.7	0.93	181.4	3.56	76.5	191.9	268.4	2.71
1990	394.6	7.58	30.0	0.94	180.8	3.55	76.1	191.0	267.2	2.69
1991	389.1	7.48	30.2	0.95	180.2	3.54	75.8	190.1	265.9	2.67
1992	363.7	6.99	30.5	0.96	179.7	3.53	75.4	189.2	264.7	2.66
1993	327.1	6.28	30.7	0.96	179.1	3.52	75.1	188.3	263.4	2.65
1994	320.4	6.14	31.0	0.97	178.5	3.51	74.7	187.4	262.2	2.63
1995	310.1	5.94	31.2	0.98	177.9	3.49	74.4	186.5	260.9	2.62
1996	285.0	5.47	30.9	0.97	179.7	3.53	70.1	175.7	245.8	2.46
1997	281.8	5.42	30.5	0.96	181.8	3.57	71.1	178.2	249.3	2.48
1998	277.4	5.33	29.9	0.94	180.3	3.54	70.3	176.2	246.5	2.45
1999	256.9	4.94	29.2	0.92	179.8	3.53	66.5	167.0	233.5	2.32
2000	245.7	4.72	29.0	0.91	180.2	3.54	66.1	165.9	232.1	2.30
2001	227.9	4.37	28.8	0.90	180.6	3.55	65.7	164.9	230.6	2.28
2002	203.5	3.89	28.5	0.90	180.9	3.55	65.3	163.8	229.2	2.27
2003	179.1	3.41	28.3	0.89	181.3	3.56	64.9	162.8	227.7	2.25
2005	178.3	3.40	28.3	0.89	183.9	3.61	65.9	165.3	231.2	2.28
2010	176.1	3.36	28.4	0.89	190.5	3.74	68.4	171.6	240.0	2.37

Part2	Symbiotic	Industrial	Sewage	Evaporation	N_2O	Leaching & runoff		Crop residues					Histosols		**Total**
	N-fixation	waste	sludge	of NH_3	emission	N-input	N_2O emission	N-in crops	Straw	Rape/Pea straw	Catch crops	N_2O emission	Area	N_2O emission	**Agricul-ture**
	N-input (mill.kg N)				(kt N_2O)	(mill.kg N)	(kt N_2O)	(mill.kg N)	mill kg straw-N removed			(kt N_2O)	(1000 ha)	(kt N_2O)	**(kt N_2O)**
1985	34.2			113.4	2.45	269.4	10.58	321.4	17.7	2.0		6.70	18.4	0.14	**35.06**
1986	38.1			113.8	2.54	263.3	10.34	318.8	18.1	2.1		6.66	18.4	0.14	**34.46**
1987	37.0		2.0	111.0	2.51	258.5	10.15	316.7	18.5	2.0		6.62	18.4	0.14	**34.08**
1988	37.5		2.0	108.4	2.48	254.6	10.00	315.0	18.8	2.0		6.60	18.4	0.14	**33.49**
1989	38.2		2.0	108.9	2.50	239.0	9.39	308.3	20.0	1.9		6.49	18.4	0.14	**32.87**
1990	39.7		2.0	109.2	2.53	233.8	9.19	304.7	19.7	1.4		6.40	18.4	0.14	**33.03**
1991	39.2	2.7	3.2	105.7	2.55	228.7	8.98	301.1	19.4	2.1		6.34	18.4	0.14	**32.66**
1992	33.7	3.0	3.8	104.1	2.43	223.5	8.78	297.5	19.1	1.7		6.25	18.4	0.14	**31.74**
1993	35.3	4.5	4.9	101.0	2.46	218.3	8.58	293.8	18.7	2.3		6.19	18.4	0.14	**30.78**
1994	38.5	4.5	4.4	97.5	2.46	213.2	8.37	290.2	18.4	1.7		6.10	18.4	0.14	**30.33**
1995	36.1	4.6	4.7	91.9	2.33	208.0	8.17	286.6	18.1	1.3		6.01	18.4	0.14	**29.70**
1996	34.2	4.2	4.6	88.5	2.23	199.0	7.82	277.8	17.9	0.9		5.83	18.4	0.14	**28.46**
1997	37.2	4.1	4.0	88.0	2.27	198.0	7.78	293.7	18.2	1.2		6.15	18.4	0.14	**28.78**
1998	42.9	4.9	4.0	88.8	2.41	196.0	7.70	297.5	18.3	1.3		6.23	18.4	0.14	**28.75**
1999	40.6	4.9	4.0	84.4	2.30	187.0	7.35	297.5	17.6	0.9	0.0	6.21	18.4	0.14	**27.71**
2000	40.6	4.9	3.8	83.9	2.29	183.0	7.19	297.5	17.6	0.9	0.8	6.22	18.4	0.14	**27.32**
2001	40.6	4.9	3.6	82.9	2.27	166.5	6.54	297.5	18.1	0.9	1.5	6.25	18.4	0.14	**26.31**
2002	40.6	4.9	3.4	79.9	2.22	150.1	5.90	297.5	19.4	0.9	2.3	6.29	18.4	0.14	**25.15**
2003	40.6	4.9	3.2	78.2	2.19	133.6	5.25	297.5	19.5	0.9	3.0	6.30	18.4	0.14	**24.00**
2005	40.6	4.9	3.2	77.1	2.17	133.6	5.25	297.5	21.4	0.9	3.0	6.34	18.4	0.14	**24.09**
2010	40.6	4.9	3.2	75.6	2.14	133.6	5.25	297.5	21.9	0.9	3.0	6.35	18.4	0.14	**24.26**

Part 3 NH_3 Emission	Synt. Fertil. emission (kt NH_3-N)	Animal Manure (kt NH_3-N)	Crops NH3 emission (kt NH_3-N)	Straw leaching NH3 emission (kt NH_3-N)	Evaporation from sludge (kt NH_3-N)	Total evaporation (kt NH_3-N)
1985	7.8	87.0	13.2	5.4	0.0	113.4
1986	7.2	86.8	13.1	6.6	0.0	113.8
1987	7.2	83.3	13.1	7.3	0.0	111.0
1988	7.0	82.4	13.0	6.0	0.0	108.4
1989	7.3	81.2	12.9	7.4	0.1	108.9
1990	8.5	79.2	13.0	8.4	0.1	109.2
1991	8.3	77.3	12.9	7.1	0.1	105.7
1992	7.8	77.1	12.8	6.3	0.1	104.1
1993	7.5	75.4	11.8	6.2	0.1	101.0
1994	7.7	71.5	11.5	6.7	0.1	97.5
1995	7.5	67.3	11.6	5.5	0.1	91.9
1996	6.5	66.1	11.6	4.2	0.1	88.5
1997	6.1	66.4	11.8	3.7	0.1	88.0
1998	6.1	67.9	11.7	3.0	0.1	88.8
1999	5.7	65.7	11.2	1.7	0.1	84.4
2000	5.5	65.2	11.1	2.0	0.1	83.9
2001	5.4	64.8	11.1	1.5	0.1	82.9
2002	5.3	62.5	11.0	1.0	0.1	79.9
2003	5.3	61.5	10.9	0.5	0.1	78.2
2005	5.2	61.1	10.8	0.0	0.1	77.1
2010	4.8	60.3	10.4	0.0	0.1	75.6

6 Land-use Change & Forestry

The total area of Denmark is 43000 km^2. About 10% or 4170 km^2 (417,000 ha) of the area was forest in 1990, this includes 60 km^2 not covered at the moment of counting [30]. The forest area is defined as the area covered with trees. This means that open woodland and open areas within the forests are not included.

At the moment there is a discussion in IPCC whether sequestration in forest can be included in the Danish totals. In this report it is assumed that CO_2 sequestration in new forests planted after 1. January 1990 can be included. The sequestration in forests existing prior to 1990 is not included in the totals in the projections in this report.

Table 22 shows the conversion factors used for the calculations. In the Danish literature an expansion factor of 2.0 is used both for broadleaves and conifers [33]. This value also includes roots and some carbon in the undergrowth and soil (IPCC default expansion factors [36] are 1.75 for undisturbed forests and 1.90 for logged forests). In order to estimate the stored amount of CO_2, the stem wood volume is first multiplied with the expansion factor to include the additional biomass apart from commercial stem wood: branches, leaves/needles, stumps and roots. This is finally multiplied with the carbon content (as CO_2 equivalents) per cubic meter.
In the default IPCC methodology the last multiplication is separated into three steps: first the roundwood volumes are converted to tons of dry biomass by multiplying with 0.65 for broadleaf trees and 0.45 for conifers, next converted to tons of carbon (by multiplying with 0.5) and finally converted to CO_2 (by multiplying with 44/12). Combining these three factors gives 1.19 t CO_2/m^3 and 0.83 t CO_2/m^3. Comparison with Table 22 shows that the Danish calculations use a lower carbon content than default IPCC values for both broadleaves and conifers. This is due to lower conversion factors for dry mass per volume of wood.

Table 22. Conversion factors

	Broadleaves	Conifers
Expansion factor	2.0	2.0
Dry mass (t/m^3)	0.58	0.38
Carbon concentration (t C/t drymass)	0.5	0.5
Carbon content (t CO_2/m^3)	1.07	0.69

6.1 CO_2 Sequestration in Existing Forests

Two hundred years ago, the forests of Denmark were exploited to such a degree that only about 2-3% of the land was covered by forest [31]. One of the consequences was a serious threat of sand drift. The trend was successfully changed and the forest area has increased until the present 10% forest cover. During the last decade, the stock of existing forests has also been increasing on a per hectare basis. The reasons for this are a distorted age distribution because of wind-throw and a diminished harvest due to current low prices.

The CO_2 uptake by existing forests has not been calculated with a model. It is based on the forest statistics. According to the Forest Act of 1989, a forest census must be produced every 10 years. The latest census [59] of the total standing volume over bark (stem wood) in 2000 showed a much higher CO_2 sequestration than for the former 10-year period. For the period 1980 to 1989 0.916 Mt CO_2 per year was sequestered in Danish forests. According to the new count it is now estimated that the average annual uptake in the period 1990-99 was four times higher, or about 3.9 Mt CO_2/year. This large increase is partly caused by the large areas regenerating from the massive fall of conifers in the storm in 1981. However, the sequestration in forest existing before 1990 is not included in the projections in the present report.

6.2 CO_2 Sequestration in New Forests

Since 1987 it has been a strategy of the Danish Government to double the forested area within the next 80-100 years, that is within about a forest generation. Using the forest model mentioned in the following it was calculated that the permanent storage in mature Danish forest is between 500 and 850 tCO_2/ha [33]. The current prognosis of afforestation is that about 200,000 ha will be afforested within the period. This would result in about 125 million tons CO_2 being stored in the first 125 years or about 1 million tons CO_2/year as an average annual sequestration over the period (see Table 24)

The CO_2 sequestration in new forests has been calculated using a model developed in Denmark [33,35,37]. As opposed to the IPCC guidelines [36], the model calculates the annual changes in the carbon stored over the whole tree generation. It does not only take into account the growth rates of the forests. It also attempts to bring into the calculation the "fate" of the stored carbon, thus recognising the "delay" in the release of carbon stored in (1) commercial wood products: fuel wood, paper and wood products with short and long lifetimes and (2) roots, leaves/needles and branches/stumps. The model uses constant five-year decomposition rates in the calculations. However, in our projections we assume that the carbon stored in the commercial wood products just replace similar wood products on the marked, which are burned after the replacement, thus resulting in no net increase of carbon stored in wood products.

The model consists of an EXCEL file with three parts: The model calculates the carbon stored annually in the 100 year period 1990-2089.
The first input to the main module of the forest model is the annual area afforested according to the Danish Afforestation Plan (see Table 23). The model operates with the two major species used for afforestation, oak (*Quercus robur*) representing broadleaves and Norway spruce (*Picea abies*) representing conifers.

Table 23. Annual area afforested.

	Broadleaves	Conifers	Total
	ha/tear		ha/year
1990	375	407	782
1991	502	544	1046
1992	627	680	1307
1993	639	693	1332
1994	689	746	1435
1995	662	717	1379
1996	686	743	1429
1997	1110	1202	2312
1998	699	758	1457
1999	1910	2069	3979
2000	1702	1037	2739
2001	1460	730	2190
2002	1836	918	2753
2003	1809	904	2713
2004	1902	951	2853
2005	1662	831	2493
2006	1662	831	2493
2007	1662	831	2493
2008	1662	831	2493
2009	1662	831	2493
2010	1662	831	2493
2011	1662	831	2493
2012	1662	831	2493
2013	1333	667	2000
2014	1333	667	2000
2015	1333	667	2000
.....			
2089	1333	667	2000

The total afforestation area for the period 1990-1999 is based on table 1 in the recent evaluation of the afforestation in the period 1989-1998 [56]. Distribution between broadleaves and conifers are based on the estimate, that 2/3 is broadleaves and 1/3 is conifers [34]. However, based on the new forest census [59] the historic distribution for 1990-1999 has been changed to 48% broadleaves and 52% conifers. Also the total afforested area has been reduced compared to the former projection [58], since it has been recognised that a large part of the afforested area has been planted with Normanns fir. These stands are more representative of short-rotation forestry, as trees are cut about 10 years for Christmas trees and greenery. Furthermore, the land-use change is not permanent, as changes in the market for Christmas trees may force land owners to revert the land use to agriculture after a few years.
The present prognosis for the years 1999-2003 do not satisfy the parliamentary agreement on the aquatic environment (Vandmiljøplan II), that 20000 ha shall be afforested during the period 1998-2003 (6 years). Only about 16000 ha is expected to be afforested. The projection for the areas afforested in the period 2004-2012 is based on information in the report from "Wilhelmudvalget" [38]. After 2012 it is assumed that the rate of afforestation is going to be equal to the level before the parliamentary decision, i.e. in average a total of 2000 hectares [38]. However, this means that we will only reach an afforestation of about 200,000 ha in 2089, e.g. a 50% increase in the forest area. In order to reach the 100% increase of the forest areas additional measures have to be implemented.

The next input to the main module of the forest model is how fast one hectare of new broad-leaved or coniferous forest sequesters CO_2 over its lifetime. This information is calculated in the two other modules “broadleaves” and “conifers”. “Broadleaves” represents the broad-leaved forest and contains empirically based yield tables for annual increment (5-year steps), thinning harvests every 10 years, and the final harvest after a rotation time of 140 years (in m^3 roundwood). “Conifers” represents the conifers and contains similar yield tables for a rotation time of 70 years. These key values are based on the experience of Danish foresters documented in [39]. The “Broadleaves” module contains yield tables for 4 different site qualities (“boniteter”) and “Conifers” includes only for 3 site qualities, since afforestation sites for conifers are assumed to be among the three best site quality classes. So far, the model only uses the values for site quality 2, since this site quality is assumed to be average.

The annual increment and thinning harvests in m^3 in “Broadleaves” and “Conifers” are then converted to CO_2 stored in the trees and the products by using the conversion factors in Table 22 and assumptions about the percentage composition of the wood product categories.

Based on these inputs the main module of the forest model separately calculates the CO_2 stored in the forest area planted each year over the next 100 years. Finally, for each of the next 100 years, the respective amounts of CO_2 stored in plantations of different age are added. The final result (without products) for the two tree types is shown in Table 24. In the first commitment period 2008-12 under the Kyoto Protocol the total absorption in new forest is 1416 kt CO_2 or equal to an average annual absorption in these five years of 283.2 kt CO_2. Table 24 also shows that the average annual sequestration until 2090 is about 0.8 Mt CO_2.

Table 24. CO_2 sequestration in new forest.

kt CO_2	Annual	Accumulated
1990	0	0
1991	1	1
1992	3	5
1993	5	10
1994	8	18
1995	10	28
1996	17	45
1997	24	69
1998	35	104
1999	44	147
2000	58	205
2001	73	278
2002	88	366
2003	110	475
2004	127	602
2005	147	749
2006	169	918
2007	189	1107
2008	**220**	1327
2009	**246**	1573
2010	**286**	1859
2011	**321**	2179
2012	**343**	2523
2020	645	6519
2030	947	14463
2040	1154	24858
2050	1273	36751
2060	1248	49510
2070	971	59826
2080	1120	70329
2090	1350	82769
2125	856	126125

6.3 CO_2 Sequestration in forest soils

According to IPCC [36] carbon stock estimates should include the total organic carbon content to a depth of 30 cm in the mineral soils as well as the carbon content of the organic layer accumulated on top of the mineral soil. A recent Danish study quantified the amounts of carbon in well-drained Danish forest soils and found an average of 125 t C/ha in the forest floor and to 1 meter depth for 140 forest sites [61]. For the forest floor and to 30 cm in the mineral soil, the carbon storage was 93 t C/ha.

The development in carbon storage over time since afforestation is currently being studied in detail, but the knowledge of differences in carbon content between agricultural soils and forest soils is still scarce for Danish conditions. However, a current Danish study aims [62] aims at quantifying the carbon pools in former agricultural soils following afforestation with oak and Norway spruce. This study could provide important input to the model calculations of carbon storage due to afforestation activities. There are a few results available for nutrient rich soils as yet, but for the organic layer alone, about 8-10 ton C/ha may be sequestered in Norway spruce stands and about 2 ton C/ha may be sequestered in oak stands after 30 years in the upper 5 centimetre of the soil [60]. There was no evidence of increased carbon content in the mineral soil 30 years after afforestation, but a similar study on nutrient-poor soil showed an increase in the upper 25 cm of the mineral soil of 23 t C/ha over 40 years [34].

However, this CO_2 sequestration in forest soil is not included in the values in Table 24, because it is still not possible to generalize for the whole country. It is assumed that the rather large expansion factor in Table 22 includes some forest soil carbon.

7 Waste

7.1 Solid Waste Disposal on Land

The former Danish Government published the last waste disposal plan "Waste 21: The Government's Waste Management Plan for the period 1998 to 2004", in May 1999 [45]. "Waste 21" puts the future waste disposal on the agenda and the plan set as a goal to stabilise the amount of waste and to improve the quality of waste treatment. This shall be obtained by reducing the influence from environmental pollutants by a higher degree of recycling of the resources in the waste. The plan has the target that 64% of the waste should be recycled in 2004, 24% incinerated and 12% landfilled (see Table 25). However, "Waste 21" does not project the production of waste in the year 2004, but with the optimistic assumption of constant total amounts from 1997, the result is that 1.5 million tonnes will be landfilled in 2004 [42] (see Table 25).

Table 25. Treatment of solid waste in Denmark 1985-2004.

Million tons	1985		1997		2004	
Recycled	3.2	35%	8.1	63%	8.3	64%
Incinerated	2.3	26%	2.6	20%	3.1	24%
Landfilled	3.5	39%	2.1	16%	1.5	12%
Special treatment	0.0	0%	0.1	1%		
Total	9.0	100%	12.9	100%	12.9	100%

The amount of solid waste being landfilled in Denmark according to source is shown in Table 27, the information is from the following sources: The first complete estimate of the solid waste was made for the year 1985 by the Danish Municipalities and Counties [40]. In 1993, the new ISAG-data system started to operate in the Ministry of Environment. According to public regulations, waste management facilities have to report the amount of waste received to the Danish Environmental Protection Agency. The data in ISAG includes the amount of waste grouped according to sources, types (like domestic waste, garden waste, industrial waste etc.), and waste management. However, only ISAG data from 1994 to 2000 [41] is used in the calculation, due to the incompleteness of the 1993 data.

From January 1, 1997 the Danish Government introduced a stop for landfilling of combustible waste [45]. Due to lack of incineration capacity part of the combustible waste will be stored temporarily before it is treated. However, it is assumed that no methane is emitted from these interim storages due to the dry conditions prevailing there.

The source of the historical data-point for the amount of waste landfilled in 1970 in Table 27, is Figure 2.16 in [43], which shows that the total amount of waste being landfilled in 1970 was 42% of the 1994 value, increasing linearly in the period 1970-1985 with the same disaggregation on source categories. A linear interpolation is also used in the periods 1985-1994 and 2000-2003 for each source category.

The disaggregation of the total amount of waste in 2004 on source categories were done using the following assumptions [42]: the amount of domestic-, bulky-, garden- and commercial waste in 2004 were assumed to be 50% of the 1997 values, the amount of industrial waste and building & construction waste in 2004 were assumed to be 75% of the 1997 values [42], the amount of sludge waste were assumed to be constant after 1999, and the small amount of ash & slag to disappear after 2004. For the period 2004-2012 the amounts of waste landfilled are kept constant for all source categories.
Since the carbon content in different fractions in the landfilled waste varies, it is necessary to make assumptions about the composition of the waste in the source categories. The assumptions are shown in Table 26 (the sum of all the fractions in each line of the table is one). All these fractions are from reference [40] except for the composition of sludge. The weight of the landfilled sludge in Table 27 includes 71% water [42], so only 29% of the sludge landfilled is in the category "other combustible".

The assumptions of the carbon content in the different fractions are shown at the bottom of Table 26. The carbon content of the fraction "other combustible" varies among the source categories from 20% in domestic waste to 57% in sludge [42]. The resulting CH_4 emission factors are also shown. They are based on the following assumption: 50% of the carbon in the landfill is emitted as a gas containing 45% CH_4, 10% of the CH_4 is oxidised in the topsoil layer [44]. The calorific value used for biogas is therefore 18 MJ/ m^3 (45% of the calorific value of CH_4, which is 40 MJ/m^3).

Table 26. Composition of landfilled waste

Material fractions in	Waste food	Card-board	Paper	Wet card-board +paper	Plas-tics	Other com-bustible	Glass	Metal	Other not com-bustible
Domestic waste	0.38	0.02	0.13	0.26	0.07	0.03	0.02	0.05	0.05
Bulky waste		0.08	0.23		0.05	0.46	0.09	0.09	0.02
Garden waste						0.76			0.24
Commercial & office waste	0.25	0.31	0.04	0.11	0.05	0.10	0.05	0.05	0.05
Industrial waste	0.06	0.02	0.07	0.01	0.01	0.06	0.04	0.18	0.54
Building & construction						0.07			0.93
Sludge						0.29			0.71
Ash & slag									1.00
Carbon content (%)	20	40	40	20	85	20-57	0	0	0
Emission factor (kg CH_4/ton)	54.0	108.0	108.0	54.0	229.5	54-154	0.0	0.0	0.0

To the right in Table 27 the calculated CH_4 emissions from Danish landfilled are shown in the column " Potential emissions". Here the emissions in a given year are calculated, using the IPCC tier 2 method, as a sum of the emissions from the waste landfilled the years before, based on the assumption of a half-life of the carbon of 10 years (e.g. ten years later always half of the carbon is converted to CH_4). Due to this calculation method there is a time-delay between the year with maximum waste landfilled (1985) and the year with the maximum potential CH_4 emissions of 68.8 kt CH_4 (1996).
In order to calculate the "actual emission" of CH_4 from landfills in Table 27, the CH_4 collection by landfill gas plants must be subtracted from then "potential emission". According to Willumsen [44] the first landfill gas plant started operating in the end of 1985. The data from this source were used until the year 1994. In the period from 1994 until 1999 the production increases from 0.333 PJ to 0.58 PJ (10.3 kt CH_4) according to the Danish Energy Agency [28]. It increases to 0.66 in 2004 and thereafter no new plants are included. From 2004 the production decreases slowly due to ageing of the plants. Table 27 shows that due to the decrease in the potential emissions and

the increase in the CH_4 collected the actual emissions in 2012 will have decreased to 38.5 kt CH_4 from the 62.4 kt CH_4 in 1990.

Table 27. Time-series for the amount of landfilled waste and annual CH_4 emissions

1000 tons	Do-mestic waste	Bul-ky waste	Gar-den waste	Com-mer-cial	Indus-trial waste	Buil-ding & Constr.	Sludge	Ash & slag	Total	Potential emission kt CH_4	kt CH_4 collec-ted	Actual emission kt CH_4
1971	92.3	96.5	72.9	25.8	375.2	778.6	168.9	184.6	1794.9	22.4	0.0	22.4
1972	100.0	104.5	79.0	28.0	406.5	843.5	183.0	200.0	1944.5	24.0	0.0	24.0
1973	107.7	112.5	85.1	30.2	437.8	908.4	197.1	215.4	2094.1	25.7	0.0	25.7
1974	115.4	120.6	91.2	32.3	469.0	973.3	211.2	230.8	2243.7	27.6	0.0	27.6
1975	123.1	128.6	97.2	34.5	500.3	1038.2	225.2	246.2	2393.2	29.6	0.0	29.6
1976	130.8	136.7	103.3	36.6	531.6	1103.0	239.3	261.5	2542.8	31.6	0.0	31.6
1977	138.5	144.7	109.4	38.8	562.8	1167.9	253.4	276.9	2692.4	33.8	0.0	33.8
1978	146.2	152.7	115.5	40.9	594.1	1232.8	267.5	292.3	2842.0	36.1	0.0	36.1
1979	153.8	160.8	121.5	43.1	625.4	1297.7	281.5	307.7	2991.5	38.4	0.0	38.4
1980	161.5	168.8	127.6	45.2	656.7	1362.6	295.6	323.1	3141.1	40.9	0.0	40.9
1981	169.2	176.8	133.7	47.4	687.9	1427.5	309.7	338.5	3290.7	43.4	0.0	43.4
1982	176.9	184.9	139.8	49.5	719.2	1492.3	323.8	353.8	3440.3	46.0	0.0	46.0
1983	184.6	192.9	145.8	51.7	750.5	1557.2	337.8	369.2	3589.8	48.6	0.0	48.6
1984	192.3	201.0	151.9	53.8	781.7	1622.1	351.9	384.6	3739.4	51.3	0.0	51.3
1985	**200.0**	**209.0**	**158.0**	**56.0**	**813.0**	**1687.0**	**366.0**	**400.0**	3889.0	54.1	0.0	54.1
1986	199.8	217.3	143.4	66.7	814.9	1539.9	337.2	427.0	3746.2	56.6	0.4	56.2
1987	199.6	225.7	128.9	77.3	816.8	1392.8	308.4	454.0	3603.4	58.8	0.4	58.5
1988	199.3	234.0	114.3	88.0	818.7	1245.7	279.7	481.0	3460.7	60.8	0.4	60.4
1989	199.1	242.3	99.8	98.7	820.6	1098.6	250.9	508.0	3317.9	62.5	0.9	61.6
1990	198.9	250.7	85.2	109.3	822.4	951.4	222.1	535.0	3175.1	64.0	1.7	62.4
1991	198.7	259.0	70.7	120.0	824.3	804.3	193.3	562.0	3032.3	65.3	1.7	63.7
1992	198.4	267.3	56.1	130.7	826.2	657.2	164.6	589.0	2889.6	66.5	1.7	64.8
1993	198.2	275.7	41.6	141.3	828.1	510.1	135.8	616.0	2746.8	67.4	2.8	64.7
1994	**198.0**	**284.0**	**27.0**	**152.0**	**830.0**	**363.0**	**107.0**	**643.0**	2604.0	68.2	2.8	65.5
1995	**190.0**	**286.0**	**17.0**	**128.0**	**779.0**	**321.0**	**101.0**	**135.0**	1957.0	68.7	6.0	62.7
1996	**132.0**	**275.0**	**6.0**	**135.0**	**822.0**	**317.0**	**117.0**	**703.0**	2507.0	68.8	6.6	62.2
1997	**83.0**	**248.0**	**6.0**	**170.0**	**707.0**	**264.0**	**130.0**	**475.0**	2083.0	68.6	9.4	59.2
1998	**98.0**	**234.0**	**20.0**	**161.0**	**746.0**	**266.0**	**124.0**	**210.0**	1859.0	68.5	10.4	58.1
1999	**117.0**	**239.0**	**3.0**	**164.0**	**582.0**	**224.0**	**126.0**	**12.0**	1467.0	68.2	9.9	58.2
2000	**85.0**	**264.0**	**7.0**	**152.0**	**611.0**	**269.0**	**94.0**	**0.0**	1482.0	67.8	10.3	57.5
2001	74.1	229.0	6.0	135.3	590.8	251.3	94.0	0.0	1380.4	67.0	10.0	57.0
2002	63.3	194.0	5.0	118.5	570.6	233.5	94.0	0.0	1278.9	65.9	10.8	55.1
2003	52.4	159.0	4.0	101.8	550.4	215.8	94.0	0.0	1177.3	64.5	11.5	53.0
2004	**41.5**	**124.0**	**3.0**	**85.0**	**530.3**	**198.0**	**94.0**	**0.0**	1075.8	62.8	11.8	51.0
2005	41.5	124.0	3.0	85.0	530.3	198.0	94.0	0.0	1075.8	61.2	11.4	49.8
2006	41.5	124.0	3.0	85.0	530.3	198.0	94.0	0.0	1075.8	59.6	11.0	48.6
2007	41.5	124.0	3.0	85.0	530.3	198.0	94.0	0.0	1075.8	58.4	10.7	47.7
2008	41.5	124.0	3.0	85.0	530.3	198.0	94.0	0.0	1075.8	57.1	10.4	46.7
2009	41.5	124.0	3.0	85.0	530.3	198.0	94.0	0.0	1075.8	55.9	10.0	45.8
2010	41.5	124.0	3.0	85.0	530.3	198.0	94.0	0.0	1075.8	54.7	9.7	45.0
2011	41.5	124.0	3.0	85.0	530.3	198.0	94.0	0.0	1075.8	51.0	9.5	41.6
2012	41.5	124.0	3.0	85.0	530.3	198.0	94.0	0.0	1075.8	47.6	9.2	38.5

7.2 Wastewater Handling

Since all wastewater in Denmark is treated aerobically, there are no emissions of CH_4 from this source.

8 References

1. Ministry of Environment and Energy: Denmark's Second National Communication on Climate Change, submitted under the United Nations Framework Convention on Climate Change. Danish Environmental Protection Agency, 1997.

2. IPCC: Climate Change 1995: The Science of Climate Change, Contribution of Working Group I to the Second Assessment Report of the IPCC. J.T. Houghton, L.G. Meira Filho, B.A. Calander, N. Harris, A. Kattenberg and K. Maskell (eds.). Cambridge University Press, Cambridge, U.K., 1996.

3. Press release from the EU-Council, No. 09402/98 (Press 205). Available on the internet.

4. Energistyrelsen: Fremskrivning af Danmarks energiforbrug, November, 2002.

5. Trafikministeriet: Regeringens handlingsplan for reduktion af transportsektorens CO_2 udslip. 1996.

6. Trafikministeriet: Transport, energi og CO_2 - emissionser, debatoplæg. December 1995.

7. European Environmental Agency: Atmospheric Emission Inventory Guidebook. www.eea/dk/aegb/

8. Fenger, J., J. Fenhann, N. Kilde: Danish Budget for Greenhouse Gases. NORD 1990:97.

9. RENDAN: Notat vedr. Forbrænding af plast i Danmark. 11. August 1998.

10. Dansk Gasteknisk Center: UHC/metan-emission fra gasmotorbaserede kraftvarmeinstallationer. Hørsholm 1996.

11. Bekendtgørelse nr. 529 af 25. juni 1999 om kvaliteten af benzin og dieselolie til brug I motorkøretøjer m.v.

12. Winther, M.: Personal communication. National Environmental Research Institute. 2001.

13. Ntziachristos, L. et al.: COPERT III - Methodology and Emission Factors (Final Draft Report). European Topic Centre on Air Emission. European Environment Agency.

14. United States Environmental Protection Agency (1994): International Anthropogenic Methane Emissions for 1990.

15. Haaland, T.: Emission af drivhusgasser i Danmark 1975-90 med særligt henblik på energisektorens bidrag. Fysisk Lab. III. Danmarks Tekniske Højskole. December 1992.

16. ELSAM/ELKRAFT : Indberetning i henhold til bekendtgørelse af 18.12.1991 om begrænsning af udledning af svovldioxid og kvælstofoxider fra kraftværker. Årlig.

17. Ahlmann-Laursen, T.: CO_2 -emissioner fra kalcinering af cement. Aalborg Portland, 1997.

18. Danmarks Statistik: Industriens salg af varer m.m. (Industri statistik). Quarterly.

19. Andersen, F.M., N. Kilde, L.H. Nielsen, S. Præstegaard: INDUS - version2 EMIS, en teknisk-økonomisk prognosemodel for industriens energiforbrug samt energirelaterede CO_2- SO_2- og NO_x- emissioner. Systemanalyseafdelingen Risø, Januar 1991.

20. Poulsen, Tomas S: Ozonlagsnedbrydende stoffer og drivhusgasserne HFC'er, PFC'er og SF_6 - Danmarks forbrug og emissioner 2001. Arbejdsrapport fra Miljøstyrelsen, December 2002.

21. Danmarks Statistik, 1999: Statistisk tiårsoversigt.

22. Danmarks Statistik: Statistisk årbog 1974-1999.

23. Andersen, J.A.: Notat om estimering af emission af methan og lattergas fra landbruget. Danmarks Miljøundersøgelser, 1999. (plus personal communication in 2000).

24. Andersen, J.M., S.G. Sommer, N.J. Hutchings, V.F. Kristensen, H.D. Poulsen. Ammoniakfordampning - redegørelse nr.1: Emission af ammoniak fra landbruget - status og kilder, Danmarks Miljøundersøgelser & Dansk Jordbrugsforskning, April 1999.

25. Kyllingsbæk, A. et al: Kvælstofbalancer i dansk landbrug, Mark- og staldbalancer. Danmark Jordbrugsforskning, december 2000.

26. Kyllingsbæk, A.: Kvælstofbalancer og kvælstofoverskud i dansk landbrug 1979-1999. Dansk Jordbrugsforskning, DJF rapport Nr. 36, November 2000.

27. Miljø- og Energiministeriet, Danmarks Miljøundersøgelser: Vandmiljøplanens Overvågningsprogram 1999, Landovervågningsoplande, faglig rapport fra DMU, nr. 334, december 2000.

28. Tafdrup, S.: Biogas: Produktion, prognose og måltal, notat fra Energistyrelsen, 26/1 2001 samt 19/9 2002.

29. Danish Institute of Agricultural and Fishery Economics: Centralised Biogas Plants, Integrated energy production, waste treatment and nutrient redistribution facilities. 1999.

30. Danmarks Statistik: Skove og Plantager 1990. Danmarks Statistik/Skov- og Naturstyrelsen, 1994.

31. Miljø & Energiministeriet 1999: Natur-og Miljøpolitisk Redegørelse 1999.

32. Danmarks Statistik, 2000: Agricultural Statistics, 1999

33. Linddal, M.: Supplerende rapport om kulstoflagring og skovrejsning. Skov- og Naturstyrelsen, Maj 1996.

34. Vesterdal, L.: Personal communication. Danish Forest and Landscape Research Institute, September 1999.

35 Linddal, M.: CO_2-binding ved skovrejsning – en miljøøkonomisk model. Skov- og Naturstyrelsen, Oktober 1994.

36. IPCC: Revised Guidelines for National Greenhouse Gas Inventories, The Intergovernmental Panel on Climate Change (IPCC), the Organisation for Economic Co-operation (OECD) and the International Energy Agency (IEA), 1997.

37. Skov- og Naturstyrelsen: Skovrejsning og CO_2-lagring, Februar 1998.

38. Thorman, A. Skov og Naturstyrelsen: Personal communication. January, 2001.

39. Møller, C. M.: Skovbrugstabeller, Statens Forstlige Forsøgsvæsen, 1979.

40. Miljøministeriet: Affaldsstrømme i Danmark. Arbejdsrapport fra Miljøstyrelsen Nr.15. 1993.

41. Miljø- og Energiministeriet: Affaldsstatistik 2000. Orientering fra Miljøstyrelsen Nr.14. 2001.

42. Hansen, Jørgen G.: Kommentar til emissionsfremskrivninger. Note fra Miljøstyrelsen, 13 April 1999. (Some changes were given in a personal communication 4th December 2000)

43. Willumsen, H.C. et al.: Analyse af mulighederne og barriererne for en udvidet udnyttelse af lossepladsgas til energiformål. Energistyrelsen, 1995.

44. Willumsen, H.C.: Fremme af lossepladsgas-udnyttelse i Danmark. LFG Consult, Viborg, December 1998.

45. Miljø- og Energiministeriet: AFFALD 21, Regeringens Affaldsplan 1998-2004. Maj 1999.

46. Andersen, J (DMU)., Jacobsen B.H (SJFI): Fremskrivning af svineproduktionen til 2012. Personlig kommunikation. 18 september 2000.

47. Olesen, J.E., Andersen, J.M., Jacobsen, B.H., Hvelplund, T., Jørgensen, U., Schou, J.S., Graversen, J., Dalgaard, T., Fenhann, J.: Kvantificering af tre tiltag til reduktion af landbrugets emission af drivhusgasser. DJF rapport 48, Danmarks Jordbrugsforskning, April 2001.

48. Olesen, J.E., Petersen, S.O., Andersen, J.M., Fenhann, J, Jacobsen, B.H.: Emission af drivhusgasser fra dansk landbrug. DJF Rapport 47, Danmarks Jordbrugsforskning, April 2001.

49. Grant, R. et al.: Vandmiljøplan II – midtvejsevaluering, Danmarks Jordbrugsforskning, december 2000.

50. Plantedirektoratet: Økologiske jordbrugsbedrifter 1999. Ministeriet for Fødevarer, Landbrug of Fiskeri. 2001.

51. Ministeriet for Fødevarer, Landbrug og Fiskeri: Udkast til regeringens redegørelse om midtvejsevalueringen af vandmiljøplan II. 15 januar 2001.

52. Ministeriet for Fødevarer, Landbrug og Fiskeri: Forslag til Handlingsplan til reduktion af ammoniakfordampningen i landbruget. 15 januar 2001.

53. Plantedirektoratet: Danmarks forbrug af handelsgødning 1999/00. Ministeriet for Fødevarer, Landbrug of Fiskeri. 2001.

54. Nielsen, K.V.: Straw quantities from the project “Vurdering af langsigtede biomasse ressourcer” Landskontoret fro Planteavl, personal communication 28 August 2000.

55. Plantedirektoratet: Økologiske jordbrugsbedrifter 1999. Ministeriet for Fødevarer, Landbrug of Fiskeri. 2001.

56. Skov- og Naturstyrelsen: Evaluering af den gennemførte skovrejsning 1989-1998. SNS, 30 May 2000.

57 Miljø & Energiministeriet 2000: Climate 2012 – Status and perspectives for Denmark’s Climate Change Policy, 2000.

58 Fenhann, J.: Denmark's Greenhouse Gas Projections until 2012, Danish Energy Agency, April 2001.

59 Larsen,. P.H., V.K. Johansen: Skove og plantager 2000. Danmarks Statistik, Skov og Landskab og Skov- og Naturstyrelsen, 2002.

60 Vesterdal, L., Ritter, E., and Gundersen, P. 2002. Change in soil organic carbon following afforestation of former arable land. Forest Ecology and Management 169: 141-151.

61 Vejre, H., Callesen, I., Vesterdal, L., and Raulund-Rasmussen, K. 2003. Organic carbon and nitrogen in Danish forest soils - contents and distribution as influenced by soil type. Soil Science Society of America Journal (in press).

62 Afforestation management in north-western Europe - influence on nitrogen leaching, groundwater recharge, and carbon sequestration. http://www.fsl.dk/afforest/

63 Sommer, S.G., H.B. Møller, S.O. Petersen: Reduktion af drivhusgasemissioner fra gylle og organisk affald ved biogasbehandling. Dansk Jordbrugsforskning, DJF rapport 31. Juli 2001.

64 Illerup, J.B. et al.: Projection models 2010. National Environmental Research Institute, to be published.

Appendix 1

Table 1. CO_2 emissions from all sectors in Denmark

kt on CO_2	Central power	Decen-tral power	District heat-plants	Indu-stry	Agricul-ture & fishery	Oil & gas ex-traction	Refineries & gas supply	Resi-dential	Ser-vice	Road trans-port	Other trans-port	Other	Elec-tricity import	Temp. Corre c-tion	Total fossil fuel Uncorrect.	Correct.	Cement etc.	NMVOC Solvent	Old forest	New forest	Kyoto total	Inter-national transport
1975	15335	0	3807	7748	2213	143	1280	10691	3089	6577	1620	127	711	1498	52503	54712	1086	119	0	0	53713	3323
1976	17434	0	4102	8535	2191	163	1172	12011	3623	6938	1687	165	662	24	57855	58542	1086	119	0	0	59065	3406
1977	19068	0	4198	8757	2199	382	1089	11754	3439	7153	1598	169	513	548	59637	60698	1086	119	0	0	60846	3321
1978	18502	0	4241	9101	2212	349	1074	11888	3166	7843	1682	175	3121	24	60058	63202	1086	119	0	0	61267	3466
1979	20651	0	4379	9236	2389	356	1224	12576	2957	7711	1789	173	2724	-1155	63267	64836	1086	119	0	0	64477	3236
1980	25225	0	3882	8576	2278	163	992	9477	2976	7373	1607	121	-1102	-441	62548	61005	997	119	0	0	63668	2943
1981	18853	0	3621	7016	2324	279	1044	8097	2583	7060	1649	135	4967	-40	52527	57454	869	119	0	0	53520	2936
1982	22499	0	3500	6386	1961	311	900	7604	2332	7285	1859	194	1818	582	54637	57037	910	119	0	0	55671	2971
1983	21264	0	3289	6082	2011	309	969	6887	2137	7612	1703	145	3769	832	52264	56864	933	119	0	0	53321	2827
1984	21522	0	3316	6739	2133	417	986	6261	2249	8189	1567	214	4321	820	53380	58521	1053	119	0	0	54557	2864
1985	27003	0	3560	6774	2249	550	912	7535	2375	8383	1521	198	399	-1295	60861	59965	1012	119	0	0	61997	2813
1986	27703	10	3095	7037	2363	665	969	7222	2147	8789	1522	206	69	-327	61522	61263	1144	117	0	0	62790	3108
1987	26859	41	2750	6606	2211	690	939	7147	2060	8734	1592	129	2116	-718	59629	61027	1100	114	0	0	60853	3959
1988	25396	90	2110	6240	2204	782	905	6107	1637	8794	1360	118	3634	337	55626	59598	1003	112	0	0	56754	4669
1989	20759	122	1782	6152	2251	767	953	5200	1382	8876	1352	122	8085	1611	49597	59294	1152	106	0	0	50874	4807
1990	22665	243	1534	6085	2276	760	886	4910	1395	9351	1268	95	6300	1879	51374	59552	1005	99	0	0	52503	4880
1991	31235	372	1678	6516	2397	1027	938	5184	1298	9756	1498	207	-1558	549	61900	60891	1179	97	0	-1	63199	4424
1992	26126	566	1364	6354	2348	1124	1043	4626	1195	9924	1307	160	2939	1171	55976	60086	1299	96	0	-3	57393	4606
1993	27561	883	1148	6303	2157	1064	1036	5354	1286	10051	1455	153	1068	-212	58299	59156	1312	94	0	-5	59731	5995
1994	31187	1527	1191	5924	2175	1121	1144	4895	1112	10558	1402	146	-3803	727	62236	59160	1311	92	0	-8	63659	6687
1995	27071	1932	1022	6195	2230	1056	1272	4955	1092	10649	1444	224	-690	235	58918	58463	1312	91	0	-10	60337	6954
1996	38671	2703	895	6279	2445	1228	1325	5310	1244	10824	1396	147	-13152	-1455	72320	57713	1388	89	0	-17	73808	6806
1997	29426	2948	693	6255	2505	1662	1095	4749	1081	11045	1312	192	-5995	419	62771	57195	1457	88	0	-24	64318	6449
1998	25545	3166	620	6309	2468	1640	957	4663	915	11222	1195	208	-3715	467	58700	55452	1436	86	0	-35	60215	6613
1999	22263	3159	544	6278	2478	2218	989	4482	951	11360	1107	175	-1918	942	55829	54853	1402	84	0	-44	57299	6475
2000	19149	3206	501	6046	2443	1994	990	3969	854	11261	1012	127	659	1343	51425	53427	1453	83	0	-58	52932	6648
2001	19971	3583	535	6104	2385	2002	987	4177	834	11302	962	163	-339	257	52842	52760	1453	78	0	-73	54301	6038
2002	22169	2441	549	6090	2421	2358	987	4152	844	11509	933	166	-4457		54453	49996	1454	73	0	-88	55892	6098
2003	23842	2483	526	6213	2455	2559	987	4104	859	11757	928	164	-6930		56713	49783	1454	69	0	-110	58127	6201

2004	26854	2441	681	6324	2485	2958	987	4044	873	11965	921	161	-10250	60533	50283	1455	64	0	-127	61925	6287
2005	27024	2511	610	6454	2508	3070	987	3985	886	12183	915	158	-10301	61134	50833	1456	60	0	-147	62503	6376
2006	28193	2497	683	6585	2528	3070	987	3944	898	12386	921	156	-11194	62692	51498	1456	55	0	-169	64034	6464
2007	28159	2475	700	6716	2545	3070	987	3922	910	12578	927	155	-10764	62989	52226	1457	51	0	-189	64307	6552
2008	28614	2392	722	6849	2562	3070	987	3888	920	12754	933	154	-10774	63692	52918	1457	68	0	-220	64997	6645
2009	28852	2371	742	6984	2577	3070	987	3858	931	12913	939	152	-10552	64222	53670	1458	68	0	-246	65502	6738
2010	28584	2357	976	7121	2592	3070	987	3827	940	13032	945	151	-9862	64431	54569	1458	68	0	-286	65672	6838
2011	28652	2335	1025	7241	2605	3025	987	3796	948	13122	951	150	-9365	64685	55320	1459	68	0	-321	65892	6930
2012	28807	2243	1047	7358	2616	3002	987	3764	955	13204	957	149	-9106	64941	55835	1459	68	0	-343	66125	7025
2013	28913	2153	1071	7472	2625	2844	987	3734	962	13273	963	147	-8865	64997	56133	1420	68	0	-397	66089	7122
2014	27370	2143	991	7582	2634	2643	987	3702	970	13332	970	146	-9040	63323	54283	1420	68	0	-400	64413	7220
2015	26817	2120	1024	7687	2642	2575	987	3670	977	13390	976	145	-8908	62865	53957	1420	68	0	-441	63913	7319
2016	26708	2124	888	7785	2650	2552	987	3648	985	13453	983	143	-9450	62763	53313	1420	68	0	-479	63773	7420
2017	26664	2128	903	7882	2657	2552	987	3626	992	13522	990	142	-9044	62902	53858	1420	68	0	-503	63889	7525

Table 2. CH_4 emissions from all sectors in Denmark

Ton CH_4	Central power	Decen-tral power	District heat-plants	Industry	Agricul-ture & fishery	Oil & gas ex-traction	Refineries & gas supply	Resi-dential	Service	Road transport	Other transport	Other	Animals	Waste	Fugitive	Kyoto total	Inter-national transport
1975	451	15	153	725	152	13	72	2028	231	2321	264	49	235484	29554	13918	285380	115
1976	464	15	165	784	140	15	65	2069	269	2428	275	61	237838	31633	13918	290080	119
1977	496	15	169	830	144	35	65	1902	255	2484	267	56	238134	33812	13918	292525	117
1978	448	15	171	857	148	32	59	2447	239	2597	274	62	239641	36083	13918	296929	122
1979	466	15	182	875	162	32	66	3685	223	2468	278	58	238198	38442	13918	299010	123
1980	483	15	167	802	185	15	54	5024	225	2301	267	51	234680	40880	13918	299017	108
1981	342	15	176	705	217	36	57	6182	197	2181	267	47	230070	43395	13860	297700	106
1982	387	15	182	660	215	45	49	6635	173	2181	277	49	225511	45979	13596	295907	107
1983	351	16	213	629	222	49	54	6594	164	2244	268	46	224554	48630	13064	297052	104
1984	352	22	268	717	264	71	58	6549	169	2340	273	54	214570	51341	13422	290415	101
1985	457	26	340	732	331	105	54	6558	187	2396	281	56	206411	54110	14436	286423	96
1986	474	29	377	760	499	129	60	6659	242	2460	278	58	200050	56238	13624	281881	102
1987	450	33	379	1024	580	161	58	7306	616	2444	271	42	190060	58454	12644	274482	127
1988	432	333	366	1064	622	188	58	6927	611	2469	275	50	183604	60422	11705	269075	139
1989	357	507	361	1153	710	191	61	6510	587	2412	269	47	180820	61576	11856	267370	142
1990	385	949	371	1179	787	190	58	6558	694	2547	263	39	182789	62369	11778	270918	142
1991	531	1365	414	1236	909	217	60	7262	728	2706	265	53	182088	63686	12361	273828	131
1992	444	2476	397	1231	828	245	64	7364	755	2739	256	47	181264	64815	12425	275304	133
1993	467	4028	353	1281	832	241	63	7856	899	2841	256	47	185566	64670	13225	282580	167
1994	550	6082	384	1229	880	261	71	7588	800	2843	242	46	179341	65459	14076	279807	186
1995	512	9096	379	1290	1249	263	83	7608	882	2862	250	57	179416	62677	14739	281306	190
1996	743	13358	379	1311	1635	311	87	7941	1167	2911	247	48	178443	62196	14133	284861	188
1997	597	14861	362	1360	2023	411	72	7898	996	2928	260	54	175329	59202	14600	280897	179
1998	559	16321	358	1416	2130	438	64	7300	891	2945	284	56	176879	58109	12426	280119	185
1999	515	16724	345	1456	2131	515	66	7132	890	2909	288	54	170551	58226	11808	273555	183
2000	415	15980	326	1410	1996	513	66	7606	869	2730	281	48	170304	57454	11741	271693	186
2001	476	17408	344	1419	2002	506	57	8103	921	2563	283	50	167194	57026	12190	270492	171
2002	829	12086	377	1422	2064	646	57	8231	930	2416	276	48	164893	55082	12203	261511	176
2003	935	11938	375	1452	2093	703	57	8282	940	2328	276	47	162784	53010	12218	257390	180
2004	1159	11723	389	1484	2122	826	57	8328	949	2224	276	45	161102	50993	12534	254166	183
2005	1165	11561	376	1509	2133	862	57	8374	959	2117	276	43	159433	49756	13095	251671	186
2006	1205	11484	390	1534	2142	862	57	8416	968	1991	276	42	157940	48627	13116	249007	189
2007	1213	11359	400	1558	2150	862	57	8389	977	1855	277	42	156493	47736	13295	246620	193

2008	1229	10878	411	1582	2156	862	57	8403	985	1711	277	41	155078	46734	13247	243609	196
2009	1239	10753	421	1606	2163	862	57	8382	992	1558	277	40	153693	45811	13292	241106	199
2010	1227	10673	440	1631	2170	862	57	8362	999	1394	278	39	152338	44961	13319	238710	203
2011	1135	10544	452	1653	2175	847	57	8370	1006	1308	278	38	151017	41590	13344	233776	207
2012	1156	10394	462	1674	2179	840	57	8379	1012	1221	279	38	149711	38455	13357	229176	210
2013	1192	10377	463	1694	2183	789	57	8389	1017	1131	280	37	149200	37765	13372	227909	214
2014	1133	10321	461	1713	2186	726	57	8395	1023	1039	280	37	149212	34989	13384	224921	217
2015	1080	10343	464	1731	2190	710	57	8401	1029	947	281	36	149185	32407	12601	221425	221
2016	1093	10358	463	1748	2193	702	57	8416	1034	903	282	35	149197	30005	12367	218818	225
2017	1092	10381	464	1764	2196	702	57	8430	1039	860	283	35	149214	27770	12311	216563	228

Table 3. N_2O emissions from all sectors in Denmark

Ton N_2O	Central power	Decen-tral power	District heat-plants	Industry	Agricul-ture & fishery	Oil & gas ex-traction	Refineries & gas supply	Resi-dential	Service	Road transport	Other transport	Other	Soils	Kyoto total	Inter-national transport
1975	430	0	102	260	95	1	25	293	83	216	53	4	35171	36729	161
1976	501	0	110	285	95	1	22	328	97	230	54	5	35171	36895	164
1977	551	0	113	293	95	3	21	320	92	238	51	5	35171	36949	154
1978	543	0	114	303	92	3	19	329	86	270	56	5	35171	36986	160
1979	616	0	118	308	98	3	22	356	80	271	51	5	35171	37095	151
1980	774	0	106	289	99	1	18	285	80	263	47	3	35171	37134	141
1981	584	0	101	251	101	3	19	257	70	253	45	4	35171	36856	148
1982	702	0	98	238	94	3	16	248	64	266	56	6	35171	36956	150
1983	667	0	96	232	97	4	17	229	59	281	50	4	35171	36902	139
1984	676	0	100	255	107	5	18	211	61	308	47	7	35171	36958	137
1985	844	0	108	258	113	7	17	243	64	315	51	6	35171	37191	131
1986	864	0	100	266	119	9	18	233	58	339	55	7	34567	36627	145
1987	841	1	96	250	109	10	17	232	56	337	55	4	34190	36194	197
1988	792	2	82	241	112	11	16	202	45	339	49	3	33598	35489	234
1989	647	3	78	239	115	11	17	174	38	378	52	3	32981	34733	239
1990	710	7	73	238	117	11	16	166	38	398	49	3	33144	34967	246
1991	979	16	79	247	121	14	18	176	36	498	59	7	32767	35010	223
1992	818	25	71	245	121	15	20	161	33	594	54	5	31854	34012	230
1993	864	40	62	243	109	15	20	181	34	683	57	5	30889	33197	321
1994	969	76	90	183	108	16	22	167	31	864	54	5	30441	33020	359
1995	833	90	88	187	106	16	24	166	31	978	59	8	29812	32389	373
1996	1187	118	87	190	112	18	25	175	34	1077	58	5	28566	31647	360
1997	896	125	87	189	115	25	20	162	31	1249	54	6	28891	31842	335
1998	773	131	84	189	113	25	17	154	26	1332	48	7	28862	31755	339
1999	667	146	78	190	114	31	18	148	29	1425	44	6	27816	30708	326
2000	562	158	73	185	112	30	18	139	27	1466	42	4	27427	30240	333
2001	596	171	75	188	109	30	20	147	26	1513	42	5	26419	29337	291
2002	682	131	81	188	111	37	20	147	26	1576	36	5	25264	28299	295
2003	740	147	74	191	112	40	20	146	26	1673	36	5	24110	27316	297
2004	852	146	79	194	114	47	20	144	27	1766	35	5	24154	27578	300
2005	856	168	66	198	115	49	20	143	27	1863	35	5	24198	27737	302
2006	891	168	69	201	116	49	20	142	27	1914	35	5	24231	27864	304
2007	887	168	71	205	116	49	20	141	27	1964	35	5	24264	27949	307

2008	898	166	72	209	117	49	20	140	28	2010	36	5	24298	28044	309
2009	904	166	74	212	118	49	20	140	28	2053	36	5	24331	28131	312
2010	901	166	81	216	118	49	20	139	28	2086	36	5	24364	28205	314
2011	891	166	84	220	119	48	20	138	28	2102	37	5	24364	28216	317
2012	905	151	86	223	119	48	20	137	28	2116	37	5	24364	28234	319
2013	913	144	85	226	120	45	20	136	28	2127	37	5	24364	28246	322
2014	824	144	83	229	120	42	20	135	29	2135	38	5	24364	28164	324
2015	792	138	84	232	120	41	20	135	29	2144	38	5	24364	28137	327
2016	778	139	80	235	121	40	20	134	29	2152	38	5	24364	28130	330
2017	778	140	80	238	121	40	20	133	29	2161	39	5	24364	28142	332

Appendix 2

Table 31: CO_2 projections 2000-2017 in the IPCC/CRF format

CO2 projections (Gg)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008-12	2013-17
Denmark's Total national Emissions and Removals (KP Net Emissions) in the base scenario ("with measures", i.e. implemented and adopted measures)	54300	55892	58126	61925	62503	64034	64308	64997	65503	65672	65892	66125	66089	64412	63912	63773	63888	65638	64415
Denmark's Total KP Removals	-73	-88	-110	-127	-147	-169	-189	-220	-246	-286	-321	-343	-397	-400	-441	-479	-503	-283	-444
Denmark's Total Emissions/Removals with LUCF (CC Net Emissions)	53384	54976	57210	61009	61587	63118	63392	64081	64587	64756	64976	65209	65173	63496	62996	62857	62972	64722	63499
Denmark's Total Emissions without LUCF	54373	55980	58236	62052	62650	64203	64497	65217	65749	65958	66213	66468	66486	64812	64353	64252	64391	65921	64859
1. Energy	52842	54453	56713	60533	61134	62602	62989	63692	64222	64431	64685	64941	64097	63323	62865	62763	62902	64394	63370
A Fuel Combustion Activities (Sectoral Approach)	52227	53943	56169	59960	60561	62118	62416	63118	63649	63858	64111	64367	64426	62764	62328	62227	62365	63821	62822
1 Energy Industries	26462	27994	29853	33348	33629	34857	34819	35213	35448	35401	35449	35513	35397	33575	32986	32723	32697	35405	33475
a Public Electricity and Heat Production	24088	25159	26851	29976	30145	31373	31336	31729	31964	31917	32011	32097	32136	30504	29961	29721	29695	31944	30403
b Petroleum Refining	987	987	987	987	987	987	987	987	987	987	987	987	987	987	987	987	987	987	987
c Manufacture of Solid Fuels and Other Energy Industries	1387	1848	2015	2385	2497	2497	2497	2497	2497	2497	2451	2428	2273	2083	2038	2015	2015	2474	2085
2 Manufacturing Industries and Construction	6104	6090	6213	6324	6454	6585	6716	6849	6984	7121	7241	7358	7472	7582	7687	7785	7882	7111	7681
3 Transport	12071	12204	12450	12654	12869	13080	13277	13461	13628	13753	13851	13940	14017	14083	14149	14220	14297	13727	14153
a Civil Aviation	131	156	164	171	179	184	190	196	202	209	216	221	227	233	240	246	253	208	240
b Road Transportation	11371	11582	11833	12043	12265	12470	12662	12840	13000	13120	13211	13295	13365	13425	13484	13549	13619	13093	13488
c Railways	211	204	204	203	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202
d Navigation	358	261	248	236	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223
4 Other Sectors	7396	7417	7418	7401	7380	7370	7376	7370	7365	7359	7348	7335	7321	7306	7290	7283	7275	7355	7295
a Commercial/Institutional	834	844	859	873	886	898	910	920	931	940	948	955	962	970	977	985	992	939	977
b Residential	4177	4152	4104	4044	3885	3844	3922	3888	3858	3827	3796	3764	3734	3702	3670	3648	3626	3827	3676
c Agriculture/Forestry/Fisheries	2385	2421	2455	2485	2508	2528	2545	2562	2577	2592	2605	2616	2625	2634	2642	2650	2657	2590	2642
5 Other (please specify: Military mobile and in projections other off road)	193	238	236	233	230	228	227	226	224	223	222	221	219	218	217	215	214	223	217
b. Mobile	193	238	236	233	230	228	227	226	224	223	222	221	219	218	217	215	214	223	217
B Fugitive Emissions from Fuels	615	509	544	573	573	573	573	573	573	573	573	573	571	560	537	537	537	573	548
1 Solid Fuels																			
2 Oil and Natural Gas	615	509	544	573	573	573	573	573	573	573	573	573	571	560	537	537	537	573	548
Flaring	615	509	544	573	573	573	573	573	573	573	573	573	571	560	537	537	537	573	548
2. Industrial Processes	1453	1454	1454	1455	1456	1456	1457	1457	1458	1458	1459	1459	1420	1420	1420	1420	1420	1458	1420
A Mineral Products	1453	1454	1454	1455	1456	1456	1457	1457	1458	1458	1459	1459	1420	1420	1420	1420	1420	1458	1420
1 Cement Production	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343
2 Lime Production	110	110	111	111	113	112	114	113	115	114	116	116	77	77	77	77	77	115	77
F Consumption of Halocarbons and Sulphur Hexafluoride																			
1 Refrigeration and Air Conditioning Equipment																			
2 Foam Blowing																			
4. Aerosols/ Metered Dose Inhalers																			
7. Electrical Equipment (SF6)																			
8 Other (please specify)																			
C3F8 (PFC used as detergent)																			
SF6 (Window plate production, Research laboratories and Running shoes)																			
3. Solvent and Other Product Use	78	73	69	64	60	55	51	68	68	68	68	68	68	68	68	68	68	68	68
A Paint Application	39	37	35	32	30	28	25	34	34	34	34	34	34	34	34	34	34	34	34
D Other (please specify: Other Products, Manufacture and Processing)	39	37	34	32	30	28	25	34	34	34	34	34	34	34	34	34	34	34	34
4. Agriculture																			
A Enteric Fermentation																			
B Manure Management																			
D Agricultural Soils																			
5. Land-Use Change and Forestry (LUCF)	-989	-1004	-1026	-1043	-1063	-1085	-1105	-1136	-1162	-1202	-1237	-1259	-1313	-1316	-1357	-1395	-1419	-1199	-1360
A Changes in Forest and Other Woody Biomass Stocks	-989	-1004	-1026	-1043	-1063	-1085	-1105	-1136	-1162	-1202	-1237	-1259	-1313	-1316	-1357	-1395	-1419	-1199	-1360
2 Temperate Forests	-989	-1004	-1026	-1043	-1063	-1085	-1105	-1136	-1162	-1202	-1237	-1259	-1313	-1316	-1357	-1395	-1419	-1199	-1360
6. Waste																			
A Solid Waste Disposal on Land																			
1 Managed Waste Disposal on Land																			
7. Other (please specify)																			
Memo Items (not included above):																			
International Bunkers	6038	6098	6201	6287	6376	6464	6552	6645	6738	6838	6930	7025	7122	7220	7319	7420	7525	6835	7321
Aviation	2421	2480	2584	2670	2758	2847	2935	3027	3121	3220	3313	3408	3505	3602	3701	3802	3908	3218	3704
Marine	3618	3618	3618	3618	3618	3618	3618	3618	3618	3618	3618	3618	3618	3618	3618	3618	3618	3618	3618
Multilateral Operations																			
CO2 Emissions from Biomass																			
CO2 Emissions related to Net Electricity Import	-339	-4457	-6930	-10250	-10301	-11194	-10784	-10774	-10552	-9862	-9385	-9106	-8865	-9040	-8908	-9450	-9044	-9932	-9081

Table 32: CH_4 projections 2000-2017 in the IPCC/CRF format

CH4 projections (Gg CO2 equivalents)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008-12	2013-17
Denmark's Total national Emissions and Removals (KP Net Emissions) in the base scenario ("with measures", i.e. implemented and adopted measures)	5677	5488	5402	5334	5281	5225	5175	5112	5059	5009	4905	4809	4782	4719	4646	4591	4544	4979	4656
Denmark's Total KP Removals																			0
Denmark's Total Emissions/Removals with LUCF (CC Net Emissions)	5677	5488	5402	5334	5281	5225	5175	5112	5059	5009	4905	4809	4782	4719	4646	4591	4544	4979	4656
Denmark's Total Emissions without LUCF	5677	5488	5402	5334	5281	5225	5175	5112	5059	5009	4905	4809	4782	4719	4646	4591	4544	4979	4656
1. Energy	968	860	870	880	880	888	887	874	870	866	861	857	856	851	832	828	827	866	839
A Fuel Combustion Activities (Sectoral Approach)	711	612	612	616	612	611	606	595	590	585	579	576	574	569	567	567	568	585	569
1 Energy Industries	393	293	293	296	293	293	291	281	279	277	273	270	269	266	265	265	266	276	266
a Public Electricity and Heat Production	383	279	278	279	275	275	272	263	261	259	255	262	253	250	260	250	251	258	251
b Petroleum Refining	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
c Manufacture of Solid Fuels and Other Energy Industries	9	13	14	16	17	17	17	17	17	17	17	17	15	14	14	14	14	17	14
2 Manufacturing Industries and Construction	30	30	31	31	32	32	33	33	34	34	35	35	36	36	36	37	37	34	36
3 Transport	55	52	50	48	46	43	40	37	34	30	29	27	25	23	21	20	19	31	22
a Civil Aviation	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1
b Road Transportation	54	51	49	47	45	42	39	36	33	30	28	26	24	22	20	19	18	31	21
c Railways	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
d Navigation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 Other Sectors	232	236	238	239	241	242	242	242	242	242	243	243	243	244	244	245	245	242	244
a Commercial/Institutional	19	20	20	20	20	20	21	21	21	21	21	21	21	21	22	22	22	21	22
b Residential	170	173	174	175	176	177	176	176	176	176	176	176	176	176	176	177	177	176	177
c Agriculture/Forestry/Fisheries	42	43	44	45	45	45	45	45	45	46	46	46	46	46	46	46	46	46	46
5 Other (please specify: Military mobile and in projections other off road)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
b. Mobile	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B Fugitive Emissions from Fuels	257	257	258	264	276	277	280	279	280	281	281	282	282	282	266	261	260	281	270
1 Solid Fuels	78	78	78	85	97	97	101	100	101	101	102	102	103	103	86	81	80	101	91
2 Oil and Natural Gas	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179
Flaring	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2. Industrial Processes																			
A Mineral Products																			
1 Cement Production																			
2 Lime Production																			
F Consumption of Halocarbons and Sulphur Hexafluoride																			
1 Refrigeration and Air Conditioning Equipment																			
2 Foam Blowing																			
4 Aerosols/ Metered Dose Inhalers																			
7. Electrical Equipment (SF6)																			
8 Other (please specify)																			
C3F8 (PFC used as detergent)																			
SF6 (Window plate production, Research laboratories and Running shoes)																			
3. Solvent and Other Product Use																			
A Paint Application																			
D Other (please specify: Other Products, Manufacture and Processing)																			
4. Agriculture	3511	3463	3418	3383	3348	3317	3286	3257	3228	3199	3171	3144	3133	3133	3133	3133	3133	3200	3133
A Enteric Fermentation	2772	2734	2697	2669	2641	2614	2587	2561	2535	2509	2484	2459	2459	2459	2459	2459	2459	2509	2459
B Manure Management	739	729	721	714	707	703	699	696	693	690	688	685	674	674	674	674	674	690	674
D Agricultural Soils																			
5. Land-Use Change and Forestry (LUCF)																			
A Changes in Forest and Other Woody Biomass Stocks																			
2 Temperate Forests																			
6. Waste	1198	1157	1113	1071	1045	1021	1002	981	962	944	873	808	793	735	681	630	583	914	684
A Solid Waste Disposal on Land	1198	1157	1113	1071	1045	1021	1002	981	962	944	873	808	793	735	681	630	583	914	684
1 Managed Waste Disposal on Land	1199	1157	1113	1071	1045	1021	1002	981	962	944	873	808	793	735	681	630	583	914	684
7. Other (please specify)																			
Memo Items (not included above):																			
International Bunkers	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	4	5
Aviation	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3
Marine	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Multilateral Operations																			
CO2 Emissions from Biomass																			
CO2 Emissions related to Net Electricity Import																			

Table 33: N_2O projections 2000-2017 in the IPCC/CRF format

N2O projections (Gg CO2 equivalents)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008-12	2013-17
Denmark's Total national Emissions and Removals (KP Net Emissions) in the base scenario ("with measures", i.e. implemented and adopted measures)	9099	8777	8473	8555	8604	8644	8670	8700	8727	8750	8754	8759	8763	8738	8730	8728	8731	8738	8738
Denmark's Total KP Removals																			0
Denmark's Total Emissions/Removals with LUCF (CC Net Emissions)	9099	8777	8473	8555	8604	8644	8670	8700	8727	8750	8754	8759	8763	8738	8730	8728	8731	8738	8738
Denmark's Total Emissions without LUCF	9099	8777	8473	8555	8604	8644	8670	8700	8727	8750	8754	8759	8763	8738	8730	8728	8731	8738	8738
1. Energy	909	946	999	1067	1103	1132	1148	1168	1185	1197	1201	1206	1211	1185	1177	1175	1179	1191	1185
A Fuel Combustion Activities (Sectoral Approach)	907	944	997	1065	1101	1131	1147	1166	1183	1196	1199	1205	1209	1183	1175	1173	1177	1190	1184
1 Energy Industries	275	294	315	353	358	370	369	372	375	376	373	373	373	344	332	327	326	374	340
a Public Electricity and Heat Production	261	277	298	334	338	350	349	353	355	356	354	354	354	326	315	309	309	354	323
b Petroleum Refining	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
c Manufacture of Solid Fuels and Other Energy Industries	8	10	11	13	14	14	14	14	14	14	13	13	12	11	11	11	11	13	11
2 Manufacturing Industries and Construction	58	58	59	60	61	62	64	65	66	67	68	69	70	71	72	73	74	67	72
3 Transport	484	502	532	561	592	608	624	638	652	662	667	672	675	678	681	684	687	658	681
a Civil Aviation	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	2	3
b Road Transportation	473	493	524	553	584	600	615	630	643	654	659	663	667	669	672	675	678	650	672
c Railways	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
d Navigation	7	5	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
4 Other Sectors	87	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88
a Commercial/Institutional	9	8	8	9	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9
b Residential	46	46	45	45	44	44	44	44	43	43	43	42	42	42	42	42	41	43	42
c Agriculture/Forestry/Fisheries	34	34	35	35	36	36	36	36	36	37	37	37	37	37	37	37	37	37	37
5 Other (please specify: Military mobile and in projections other off road)	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
b. Mobile	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
B Fugitive Emissions from Fuels	2	1	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	2	2
1 Solid Fuels																			
2 Oil and Natural Gas	2	1	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	2	2
Flaring	2	1	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	2	2
2. Industrial Processes																			
A Mineral Products																			
1 Cement Production																			
2 Lime Production																			
F Consumption of Halocarbons and Sulphur Hexafluoride																			
1 Refrigeration and Air Conditioning Equipment																			
2 Foam Blowing																			
4. Aerosols/ Metered Dose Inhalers																			
7 Electrical Equipment (SF6)																			
8 Other (please specify)																			
C3F8 (PFC used as detergent)																			
SF6 (Window plate production, Research laboratories and Running shoes)																			
3. Solvent and Other Product Use																			
A Paint Application																			
D Other (please specify: Other Products, Manufacture and Processing)																			
4. Agriculture	8190	7832	7474	7488	7501	7512	7522	7532	7543	7553	7553	7553	7553	7553	7553	7553	7553	7547	7553
A Enteric Fermentation																			
B Manure Management	721	716	712	717	723	728	734	739	745	750	750	750	750	750	750	750	750	747	750
D Agricultural Soils	7469	7116	6763	6771	6779	6784	6788	6793	6798	6803	6803	6803	6803	6803	6803	6803	6803	6800	6803
5. Land-Use Change and Forestry (LUCF)																			
A Changes in Forest and Other Woody Biomass Stocks																			
2 Temperate Forests																			
6. Waste																			
A Solid Waste Disposal on Land																			
1 Managed Waste Disposal on Land																			
7. Other (please specify)																			
Memo Items (not included above):																			
International Bunkers	90	91	92	93	94	94	95	96	97	97	98	99	100	101	101	102	103	97	101
Aviation	20	21	22	22	23	24	24	25	26	27	28	28	29	30	31	32	32	27	31
Marine	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71
Multilateral Operations																			
CO2 Emissions from Biomass																			
CO2 Emissions related to Net Electricity Import																			

Table 34: HFCs projections 2000-2017 in the IPCC/CRF format

HFCs emissions (Gg CO2 equivalents, actual emissions)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008-12	2013-17
Denmark's Total national Emissions and Removals (KP Net Emissions) in the base scenario ("with measures", i.e. implemented and adopted measures)	668	704	724	746	764	703	712	704	682	656	606	542	500	429	374	308	262	638	374
Denmark's Total KP Removals																			0
Denmark's Total Emissions/Removals with LUCF (CC Net Emissions)	668	704	724	746	764	703	712	704	682	656	606	542	500	429	374	308	262	638	374
Denmark's Total Emissions without LUCF	668	704	724	746	764	703	712	704	682	656	606	542	500	429	374	308	262	638	374
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																			
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: Military mobile and in projections other off road)																			
b. Mobile																			
B Fugitive Emissions from Fuels																			
1 Solid Fuels																			
2 Oil and Natural Gas																			
Flaring																			
2. Industrial Processes	668	704	724	746	764	703	712	704	682	656	606	542	500	429	374	308	262	638	374
A Mineral Products																			
1 Cement Production																			
2 Lime Production																			
F Consumption of Halocarbons and Sulphur Hexafluoride	668	704	724	746	764	703	712	704	682	656	606	542	500	429	374	308	262	638	374
1 Refrigeration and Air Conditioning Equipment	477	518	535	549	558	570	580	573	558	540	500	447	416	384	321	268	229	524	319
2 Foam Blowing	186	181	189	198	206	133	132	131	124	116	106	95	84	65	52	41	33	115	55
4. Aerosols/ Metered Dose Inhalers	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 Electrical Equipment (SF6)																			
8 Other (please specify)																			
C3F8 (PFC used as detergent)																			
SF6 (Window plate production, Research laboratories and Running shoes)																			
3. Solvent and Other Product Use																			
A Paint Application																			
D Other (please specify: Other Products, Manufacture and Processing)																			
4. Agriculture																			
A Enteric Fermentation																			
B Manure Management																			
D Agricultural Soils																			
5. Land-Use Change and Forestry (LUCF)																			
A Changes in Forest and Other Woody Biomass Stocks																			
2 Temperate Forests																			
6. Waste																			
A Solid Waste Disposal on Land																			
1 Managed Waste Disposal on Land																			
7. Other (please specify)																			
Memo Items (not included above):																			
International Bunkers																			
Aviation																			
Marine																			
Multilateral Operations																			
CO2 Emissions from Biomass																			
CO2 Emissions related to Net Electricity Import																			

Table 35: PFCs projections 2000-2017 in the IPCC/CRF format

PFCs projections (Gg CO2 equivalents, actual emissions)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008-12	2013-17
Denmark's Total national Emissions and Removals (KP Net Emissions) in the base scenario ("with measures", i.e. implemented and adopted measures)	18	19	18	17	17	17	17	17	18	18	18	18	18	19	19	19	19	18	19
Denmark's Total KP Removals																			0
Denmark's Total Emissions/Removals with LUCF (CC Net Emissions)	18	19	18	17	17	17	17	17	18	18	18	18	18	19	19	19	19	18	19
Denmark's Total Emissions without LUCF	18	19	18	17	17	17	17	17	18	18	18	18	18	19	19	19	19	18	19
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																			
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: Military mobile and in projections other off road)																			
b. Mobile																			
B Fugitive Emissions from Fuels																			
1 Solid Fuels																			
2 Oil and Natural Gas																			
Flaring																			
2. Industrial Processes	18	19	18	17	17	17	17	17	18	18	18	18	18	19	19	19	19	18	19
A Mineral Products																			
1 Cement Production																			
2 Lime Production																			
F Consumption of Halocarbons and Sulphur Hexafluoride	18	19	18	17	17	17	17	17	18	18	18	18	18	19	19	19	19	18	19
1 Refrigeration and Air Conditioning Equipment	16	16	17	17	17	17	17	17	18	18	18	18	18	19	19	19	19	18	19
2 Foam Blowing																			
4. Aerosols/ Metered Dose Inhalers																			
7. Electrical Equipment (SF6)																			
8 Other (please specify)	2	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C3F8 (PFC used as detergent)	2	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF6 (Window plate production, Research laboratories and Running shoes)																			
3. Solvent and Other Product Use																			
A Paint Application																			
D Other (please specify: Other Products, Manufacture and Processing)																			
4. Agriculture																			
A Enteric Fermentation																			
B Manure Management																			
D Agricultural Soils																			
5. Land-Use Change and Forestry (LUCF)																			
A Changes in Forest and Other Woody Biomass Stocks																			
2 Temperate Forests																			
6. Waste																			
A Solid Waste Disposal on Land																			
1 Managed Waste Disposal on Land																			
7. Other (please specify)																			
Memo Items (not included above):																			
International Bunkers																			
Aviation																			
Marine																			
Multilateral Operations																			
CO2 Emissions from Biomass																			
CO2 Emissions related to Net Electricity Import																			

Table 36: SF_6 projections 2000-2017 in the IPCC/CRF format

SF6 projections (Gg CO2 equivalents, actual emissions)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008-12	2013-17
Denmark's Total national Emissions and Removals (KP Net Emissions) in the base scenario ("with measures", i.e. implemented and adopted measures)	30	29	29	27	27	28	28	28	28	28	61	107	117	129	115	87	72	50	104
Denmark's Total KP Removals																			0
Denmark's Total Emissions/Removals with LUCF (CC Net Emissions)	30	29	29	27	27	28	28	28	28	28	61	107	117	129	115	87	72	50	104
Denmark's Total Emissions without LUCF	30	29	29	27	27	28	28	28	28	28	61	107	117	129	115	87	72	50	104
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																			
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: Military mobile and in projections other off road)																			
b. Mobile																			
B Fugitive Emissions from Fuels																			
1 Solid Fuels																			
2 Oil and Natural Gas																			
Flaring																			
2. Industrial Processes	30	29	29	27	27	28	28	28	28	28	61	107	117	129	115	87	72	50	104
A Mineral Products																			
1 Cement Production																			
2 Lime Production																			
F Consumption of Halocarbons and Sulphur Hexafluoride	30	29	29	27	27	28	28	28	28	28	61	107	117	129	115	87	72	50	104
1 Refrigeration and Air Conditioning Equipment																			
2 Foam Blowing																			
4 Aerosols/ Metered Dose Inhalers																			
7 Electrical Equipment (SF6)	13	11	12	12	12	13	13	13	13	14	14	14	15	15	15	15	16	14	15
8 Other (please specify)	16	18	17	15	15	15	15	15	15	15	47	93	102	114	100	72	56	37	89
C3F8 (PFC used as detergent)																			
SF6 (Window plate production, Research laboratories and Running shoes)	18	18	17	15	15	15	15	15	15	15	47	93	102	114	100	72	56	37	89
3. Solvent and Other Product Use																			
A Paint Application																			
D Other (please specify: Other Products, Manufacture and Processing)																			
4. Agriculture																			
A Enteric Fermentation																			
B Manure Management																			
D Agricultural Soils																			
5. Land-Use Change and Forestry (LUCF)																			
A Changes in Forest and Other Woody Biomass Stocks																			
2 Temperate Forests																			
6. Waste																			
A Solid Waste Disposal on Land																			
1 Managed Waste Disposal on Land																			
7. Other (please specify)																			
Memo Items (not included above):																			
International Bunkers																			
Aviation																			
Marine																			
Multilateral Operations																			
CO2 Emissions from Biomass																			
CO2 Emissions related to Net Electricity Import																			

Table 37: Total GHGs projections 2000-2017 in the IPCC/CRF format

GHG projections (Gg CO2 equivalents)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008-12	2013-17
Denmark's Total national Emissions and Removals (KP Net Emissions) in the base scenario ("with measures", i.e. implemented and adopted measures)	69792	70910	72771	76604	77198	78651	78911	79558	80017	80134	80236	80360	80269	78446	77795	77505	77517	80061	78306
Denmark's Total KP Removals	-73	-88	-110	-127	-147	-169	-189	-220	-248	-286	-321	-343	-397	-400	-441	-479	-503	-283	-444
Denmark's Total Emissions/Removals with LUCF (CC Net Emissions)	68876	69994	71855	75688	76282	77735	77995	78642	79101	79218	79320	79444	79353	77530	76879	76589	76601	79145	77390
Denmark's Total Emissions without LUCF	69865	70997	72881	76731	77345	78820	79100	79778	80263	80420	80557	80703	80666	78846	78236	77984	78019	80344	78750
1. Energy	54719	56267	58582	62480	63126	64712	65024	65733	66277	66495	66747	67004	67064	65360	64874	64766	64908	66451	65394
A Fuel Combustion Activities (Sectoral Approach)	53845	55499	57779	61640	62275	63860	64169	64879	65422	65639	65890	66148	66209	64516	64070	63967	64110	65595	64574
1 Energy Industries	27131	28581	30461	33098	34280	35519	35478	35866	36102	36055	36095	36156	36039	34184	33582	33314	33290	36055	34082
a Public Electricity and Heat Production	24732	25716	27427	30589	30758	31997	31956	32344	32580	32533	32619	32703	32743	31080	30525	30280	30255	32556	30977
b Petroleum Refining	994	994	994	994	994	994	994	994	994	995	995	995	995	995	995	995	995	995	995
c Manufacture of Solid Fuels and Other Energy Industries	1404	1871	2040	2414	2528	2528	2528	2528	2528	2528	2481	2458	2301	2109	2063	2040	2040	2504	2110
2 Manufacturing Industries and Construction	6192	6178	6303	6415	6547	6679	6812	6947	7083	7222	7344	7463	7578	7689	7795	7895	7992	7212	7790
3 Transport	12610	12758	13032	13263	13506	13731	13941	14136	14313	14446	14547	14639	14717	14785	14851	14924	15003	14416	14856
a Civil Aviation	133	158	166	174	181	187	193	199	205	212	218	224	230	237	243	250	257	211	243
b Road Transportation	11899	12127	12408	12644	12893	13112	13317	13508	13677	13803	13898	13984	14056	14118	14176	14243	14314	13773	14181
c Railways	213	208	206	205	204	204	204	204	204	204	204	204	204	204	204	204	204	204	204
d Navigation	365	266	253	241	228	228	228	228	228	228	228	228	228	228	228	228	228	228	228
4 Other Sectors	7715	7740	7744	7729	7709	7700	7707	7701	7696	7690	7679	7666	7652	7637	7622	7615	7608	7686	7627
a Commercial/Institutional	861	872	887	901	915	927	939	949	960	969	978	985	993	1000	1008	1015	1023	968	1008
b Residential	4393	4370	4323	4263	4205	4165	4142	4108	4077	4046	4014	3983	3952	3920	3889	3866	3844	4046	3894
c Agriculture/Forestry/Fisheries	2460	2498	2534	2565	2589	2608	2626	2643	2659	2674	2687	2698	2708	2717	2726	2734	2741	2672	2725
5 Other (please specify: Military mobile and in projections other off road)	197	242	239	236	233	231	230	229	228	226	225	224	223	221	220	219	217	226	220
b. Mobile	197	242	239	236	233	231	230	229	228	226	225	224	223	221	220	219	217	226	220
B Fugitive Emissions from Fuels	874	768	803	839	851	852	855	854	855	856	856	857	855	843	804	790	798	856	820
1 Solid Fuels	78	78	78	85	97	97	101	100	101	101	102	102	103	103	86	81	80	101	91
2 Oil and Natural Gas	796	690	725	754	754	754	754	754	754	754	754	754	752	741	718	718	718	754	720
Flaring	618	512	546	576	576	576	576	576	576	576	576	576	574	562	539	539	539	576	551
2. Industrial Processes	2169	2206	2225	2245	2265	2203	2214	2206	2186	2160	2144	2126	2055	1997	1927	1834	1773	2165	1917
A Mineral Products	1453	1454	1454	1455	1456	1456	1457	1457	1458	1458	1459	1459	1420	1420	1420	1420	1420	1458	1420
1 Cement Production	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343	1343
2 Lime Production	110	110	111	111	113	112	114	113	115	114	116	116	77	77	77	77	77	115	77
F Consumption of Halocarbons and Sulphur Hexafluoride	716	752	771	791	809	748	757	750	728	703	685	667	635	577	507	414	353	706	497
1 Refrigeration and Air Conditioning Equipment	493	534	552	586	578	588	597	590	575	558	518	465	434	392	340	285	248	541	338
2 Foam Blowing	186	181	189	198	206	133	132	131	124	116	106	95	84	65	52	41	33	115	55
4. Aerosols/ Metered Dose Inhalers	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7. Electrical Equipment (SF6)	13	11	12	12	12	13	13	13	13	14	14	14	15	15	15	15	16	14	15
8 Other (please specify)	20	20	18	15	15	15	15	15	15	15	47	93	102	114	100	72	56	37	89
C3F8 (PFC used as detergent)	2	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF6 (Window plate production, Research laboratories and Running shoes)	18	18	17	15	15	15	15	15	15	15	47	93	102	114	100	72	56	37	89
3. Solvent and Other Product Use	78	73	69	64	60	55	51	68	68	68	68	68	68	68	68	68	68	68	68
A Paint Application	39	37	35	32	30	28	25	34	34	34	34	34	34	34	34	34	34	34	34
D Other (please specify: Other Products, Manufacture and Processing)	39	37	34	32	30	28	26	34	34	34	34	34	34	34	34	34	34	34	34
4. Agriculture	11701	11295	10893	10871	10849	10828	10808	10789	10770	10752	10724	10697	10686	10686	10686	10686	10686	10746	10686
A Enteric Fermentation	2772	2734	2697	2669	2641	2614	2587	2561	2535	2509	2484	2459	2459	2459	2459	2459	2459	2509	2459
B Manure Management	1460	1445	1433	1431	1429	1431	1433	1435	1437	1440	1438	1435	1424	1424	1424	1424	1424	1437	1424
D Agricultural Soils	7469	7116	6763	6771	6779	6784	6788	6793	6798	6803	6803	6803	6803	6803	6803	6803	6803	6800	6803
5. Land-Use Change and Forestry (LUCF)	-989	-1004	-1026	-1043	-1063	-1085	-1105	-1136	-1162	-1202	-1237	-1259	-1313	-1316	-1357	-1395	-1419	-1199	-1360
A Changes in Forest and Other Woody Biomass Stocks	-989	-1004	-1026	-1043	-1063	-1085	-1105	-1136	-1162	-1202	-1237	-1259	-1313	-1316	-1357	-1395	-1419	-1199	-1360
2 Temperate Forests	-989	-1004	-1026	-1043	-1063	-1085	-1105	-1136	-1162	-1202	-1237	-1259	-1313	-1316	-1357	-1395	-1419	-1199	-1360
6. Waste	1198	1157	1113	1071	1045	1021	1002	981	962	944	873	808	793	735	681	630	583	914	684
A Solid Waste Disposal on Land	1198	1157	1113	1071	1045	1021	1002	981	962	944	873	808	793	735	681	630	583	914	684
1 Managed Waste Disposal on Land	1198	1157	1113	1071	1045	1021	1002	981	962	944	873	808	793	735	681	630	583	914	684
7. Other (please specify)																			
Memo Items (not included above):																			
International Bunkers	6132	6193	6297	6384	6473	6563	6652	6745	6839	6939	7033	7129	7226	7325	7425	7527	7633	6037	7427
Aviation	2442	2503	2607	2694	2783	2873	2962	3055	3149	3250	3343	3439	3536	3635	3735	3837	3943	3247	3737
Marine	3690	3690	3690	3690	3690	3690	3690	3690	3690	3690	3690	3690	3690	3690	3690	3690	3690	3690	3690
Multilateral Operations																			
CO2 Emissions from Biomass																			
CO2 Emissions related to Net Electricity Import	-339	-4457	-8930	-10250	-10301	-11194	-10784	-10774	-10652	-9882	-9385	-9106	-8865	-9040	-8908	-9450	-9044	-9932	-9081