
# EMISSION INVENTORY FOR FUGITIVE EMISSIONS IN DENMARK

NERI Technical Report no. 739 2009

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# Data sheet


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Abstract: This report presents the methodology and data used in the Danish inventory of fugitive emissions from fuels for the years until 2007. The inventory of fugitive emissions includes $CO_2$, $CH_4$, $N_2O$, $NO_x$, CO, NMVOC, $SO_2$, dioxin, PAH and particulate matter. In 2007 the total Danish emission of greenhouse gasses was 66 641 Gg $CO_2$-eqvivalents. Fugitive emissions from fuels account for 496 Gg $CO_2$-eqvivalents or approximately 1 %. The major part of the fugitive emissions are emitted as $CO_2$ (74 %) due to flaring of oil and gas. The major source of fugitive $CH_4$ emission is extraction of oil and gas in the North Sea, refining of oil and loading of oil onto ships both offshore and onshore. The fugitive emissions of NMVOC originate for the major part from extraction, loading of ships, transmission and distribution of oil and to a much lesser degree from natural gas and fugitive emissions from gas stations. The total Danish emission of NMVOC in 2007 is 103 Gg. Fugitive emissions account for 13 Gg, which corresponds to 13 %. Time series for emissions are presented for the years 1990-2007, except for particulate matter where the time series covers 2000-2007. Further, projections are described for the years 2008-2030.



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# Contents

# Preface

The National Environmental Research Institute, Aarhus University (NERI) prepares the national inventories of emissions to the air and carries out the reporting to the UNFCCC (United Nations Framework Convention Climate Change) and to the UNECE CLRTAP (United Nations Economic Commission for Europe Convention on Long Range Transboundary Pollutants) on an annual basis. Furthermore, the greenhouse gas emission inventory is reported to the EU monitoring mechanism, the Kyoto Protocol and to the NEC directive (National Emission Ceilings for certain atmospheric pollutants).

This report summarizes the methods and data foundation used for quantification of fugitive emissions from fuels. It includes the latest updates and improvements to emission inventory and projections of fugitive emissions. Also, planed future improvements are listed. Data given in this report is based on the national emission inventory for the year 2007, which are described in full in Denmark's National Inventory Report 2009.

# Summary

In 2007 the total Danish emission of greenhouse gasses was 66 641 Gg carbon dioxide ($CO_2$) eqvivalents. Fugitive emissions from fuels account for 496 Gg $CO_2$ eqvivalents or approximately 1 %. The major part of the fugitive emissions are emitted as $CO_2$ (74 %) due to flaring of oil and gas. The major source of fugitive methane ($CH_4$) emission is extraction of oil and gas in the North Sea, refining of oil and loading of oil onto ships both offshore and onshore.

Beside the greenhouse gasses $CO_2$, $CH_4$ and nitrous oxide ($N_2O$) the inventory on fugitive emissions from fuels also includes emissions of nitrogen oxide ($NO_x$), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), sulphur dioxide ($SO_2$), dioxin, fluoranthene and particles. Flaring offshore and in the refineries is the only source to $SO_2$, $N_2O$, $NO_x$, dioxin and CO. The fugitive emissions of NMVOC originate for the major part from extraction, loading of ships, transmission and distribution of oil and to a much lesser degree from natural gas and fugitive emissions from filling stations. The emission of particulate matter (PM) comes from storage of solid fuels (coal piles).

In accordance with the Intergovernmental Panel on Climate Change (IPCC) definitions the inventory of fugitive emissions (Sector 1B) is segmented into sub-categories covering emissions from solid fuels (1B1c), from oil (1B2a) from natural gas (1B2b) and from venting and flaring (1B2c). In the Danish emission database emissions are held on SNAP level (Selected Nomenclature for Air Pollution) and afterwards aggregated according to the reporting formats.

The emission inventory is based on data from a number of data suppliers and emission factors. The overall method for estimating emissions is to multiply an activity by an emission factor. The data foundation and the adopted methods are outlined on sub-sector level in this report. The greenhouse gas emissions are calculated for the years 1990-2007 according to the reporting requirements. Further, projections are made for the years 2008-2030. The projection of fugitive emissions is based on the prognosis for the production of oil and gas, the Danish Energy projection and on extrapolation from the historical data. Political decisions and technological progresses are incorporated when possible, mainly in relation to the emission factors.

In order to ensure completeness in the emission inventory, future improvements have been identified and will be incorporated in the future. The identified future improvements cover emissions from storage tanks, from distribution of town gas and improvement of the inventory of emissions from offshore extraction of oil and gas.

# Sammendrag

I 2007 var den samlede danske emission af drivhusgasser 66.641 Gg kuldioxid ($CO_2$) -ækvivalenter. Heraf er 496 Gg $CO_2$-ækvivalenter, svarende til knapt 1 %, flygtige emissioner. Størstedelen af de flygtige emissioner i Danmark udledes som $CO_2$ (74 %) fra flaring af olie og gas. Den største kilde til flygtig emission af metan ($CH_4$) er udvinding af olie og gas i Nordsøen, raffinering af olie og lastning af skibe både offshore og onshore. Lattergas ($N_2O$) kommer hovedsageligt fra flaring (afbrænding af olie og gas uden nyttiggørelse men af tekniske og sikkerhedsmæssige årsager) offshore i forbindelse med udvinding af olie og gas i Nordsøen og på de to danske raffinaderier.

Udover drivhusgasserne $CO_2$, $CH_4$ og $N_2O$ dækker opgørelsen af flygtige emissioner også luftforureningskomponenterne kvælstofilter ($NO_x$), kulilte (CO), flygtige kulbrinter – *andre flygtige organiske forbindelser end metan* (NMVOC), svovldioxid ($SO_2$), dioxin, fluoranthen og partikler. Flaring i Nordsøen og på raffinaderierne er den største kilde til flygtig emission af $SO_2$, $NO_x$, dioxin og CO. Flygtige emissioner af NMVOC stammer hovedsageligt fra udvinding af olie og gas, lastning af skibe, transmission og distribution af olie og i mindre grad gas, samt fra flygtige emissioner fra tankstationer. Partikelemissionen som indgår i opgørelsen af flygtige emissioner stammer alene fra lagring af fast brændsel (kulbunker).

I overensstemmelse med Intergovernmental Panel on Climate Change (IPCC) guidelines er flygtige emissioner (sektor 1B) inddelt i fire under-sektorer der omfatter emissioner fra fast brændsel (1B1c), fra olie (1B2a), fra gas (1B2b) og fra afblæsning (venting) og flaring (1B2c). I den danske emissionsdatabase er aktiviteterne lagret på SNAP-niveau (Selected Nomenclature for Air Pollution), og emissionerne estimeres og aggregeres efterfølgende i overensstemmelse med rapporteringsformaterne.

Emissionsopgørelsen er baseret på data fra et antal dataleverandører og et sæt emissionsfaktorer. Den generelle metode til at estimere en emission er ved at multiplicere en aktivitet med en emissionsfaktor. Datagrundlaget og de anvendte metoder for flygtige emissioner er gennemgået på under-sektorniveau i denne rapport. Emissionerne er beregnet for årene 1990-2007 i overensstemmelse med rapporteringskravene. Desuden er der lavet fremskrivning af emissionerne for årene frem til 2030. Fremskrivningen af flygtige emissioner er baseret på prognosen for produktion af olie og gas, den danske energifremskrivning og på ekstrapolation af historiske emissioner. Politiske beslutninger og tekniske fremskridt bliver inddraget i fremskrivningerne, hovedsageligt i relation til emissionsfaktorer.

For at gøre opgørelsen komplet er der identificeret områder til forbedring. Disse vil blive indarbejdet i fremtidige opgørelser i takt med at datagrundlaget bliver tilvejebragt. De fremtidige forbedringer dækker emissioner fra lagring af olieprodukter i tankanlæg og fra distribution

af bygas, samt forbedring af opgørelsen for emissioner fra udvinding af olie og gas.

# 1 Total Danish emissions, international conventions and reduction targets

The Danish emission inventories follow the 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines and IPCC Good Practice Guidance. The inventories are based on the European programme for emission inventories, the CORINAIR system, which includes methodology, structure and software. The emission data are stored in a MS Access database, from where it is transferred to the reporting formats. The methodology is outlined in the European Monitoring and Evaluation Programme/CORe INventory AIR emissions (EMEP/CORINAIR) Guidebook 3rd edition, prepared by the United Nations Economic Commission for Europe/European Monitoring and Evaluation Programme (UNECE/EMEP) Task Force on Emission Inventories and Projections (EMEP/CORINAIR, 2007).

In the national inventory the emissions are organized in six categories, according to the reporting formats for the United Nations Economic Commission for Europe Convention on Long Range Transboundary Pollutants (UNECE CLRTAP) convention and the Climate Convention. These categories cover emissions from Energy, Industrial Processes, Solvents and Other Product Use, Agriculture, Land use - Land use change and forestry and Waste. The Danish emission database is organized according to the Selected Nomenclature for Air Pollution (SNAP) as defined in the CORINAIR system. The emission inventories are prepared from a complete emission database based on the SNAP sectors. Aggregation to the sector codes used for both the UNECE CLRTAP and the United Nations Framework Convention Climate Change (UNFCCC) is based on a correspondence list between SNAP and IPCC sectors. Data presented in the present report is based on the Danish emission inventories 2009 including emissions for the year 2007.

The National Emission Inventory 2009 is published on the homepage http://www2.dmu.dk/Pub/FR724.pdf for the National Environmental Research Institute, NERI. NERI's homepage also holds tables with emissions and emission factors all being updated on a yearly basis on the following homepage:
www.dmu.dk/Luft/Emissioner/Home+of+Inventory/
Furthermore, the data reported to the UNFCCC, UNECE CLRTAP and the EU Monitoring Mechanism can be found on the EIONET homepage: http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories.

## 1.1 International conventions and reduction targets

Denmark is a party to two international conventions with regard to air emissions; the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP or the Geneva Convention) and the UN Framework Convention on Climate Change (UNFCCC). The latter is also called the Climate Convention.

CLRTAP is a framework convention and has expanded to cover eight protocols:

1. EMEP Protocol, 1984 (Geneva).
2. Protocol on Reduction of Sulphur Emissions, 1985 (Helsinki).
3. Protocol concerning the Control of Emissions of Nitrogen Oxides, 1988 (Sofia).
4. Protocol concerning the Control of Emissions of Volatile Organic Compounds, 1991 (Geneva).
5. Protocol on Further Reduction of Sulphur Emissions, 1994 (Oslo).
6. Protocol on Heavy Metals, 1998 (Aarhus).
7. Protocol on Persistent Organic Pollutants (POPs), 1998 (Aarhus).
8. Protocol to Abate Acidification, Eutrophication and Ground-level Ozone, 1999 (Gothenburg).

The Climate Convention is a framework convention from 1992. The objective of the convention is "to achieve (…) stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The convention does not hold obligations concerning reduction of emissions but encourage the parties to reduce the emissions of greenhouse gases to their 1990 level. An important point is that the parties to the convention are obligated to make national inventories of anthropogenic emissions of sources and removals by sinks of greenhouse gases.

The Kyoto Protocol is a protocol to the Climate Convention. The Kyoto Protocol sets legally binding emission targets and timetables for the following greenhouse gases: $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs and $SF_6$. The greenhouse gas emissions of the pollutants are combined to $CO_2$-equivalents, which can be summarized to produce total greenhouse gas (GHG) emissions. Denmark is a party to the Kyoto Protocol and is obligated to reduce the emission of GHG in the commitment period (2008-2012) by 8 % compared to the base year emission level (1990 for $CO_2$, $CH_4$ and $N_2O$ and 1995 for the F-gasses). EU is also a party to the Climate Convention with an individual reduction obligation of 8 %. The 15 EU countries (EU-15) that compose EU as a party to the Kyoto Protocol have distributed this reduction obligation among themselves according to the Burden Sharing Agreement. Hereby the countries have obligated themselves to submit emission data to the EU monitoring mechanism for $CO_2$ and other greenhouse gases. According to the Burden Sharing Agreement Denmark is obligated to reduce its GHG emission be 21 % in 2008-2012 according to the emission in the base year (see table 1.5).

## 1.2 Total Danish emissions

The Danish 2007 emissions reported to the conventions are summarised in Table 1.1, 1.2, 1.3 and 1.4. The emissions are aggregated on sector level according to the reporting formats.

Table 1.1 GHG emission 2007 in Gg $CO_2$ equivalents as reported to UNFCCC (Nielsen et al. 2009a).

| Sector | $CO_2$ | $CH_4$ | $N_2O$ | HFCs | PFCs | $SF_6$ | Total |
|---|---|---|---|---|---|---|---|
| Energy | 51 494 | 595 | 458 | 0 | 0 | 0 | 52 546 |
| Industrial Processes | 1 647 | - | - | 840 | 15 | 30 | 2 533 |
| Solvent and Other Product Use | 87 | 0 | 37 | 0 | 0 | 0 | 124 |
| Agriculture | 0 | 3 835 | 6 238 | 0 | 0 | 0 | 10 072 |
| Land Use, Land-Use Change and Forestry | -1 127 | 0 | 0 | 0 | 0 | 0 | -1 128 |
| Waste | - | 1 319 | 47 | 0 | 0 | 0 | 1 366 |
| Denmark Total excl. LULUCF | | | | | | | 66 641 |
| Denmark Total incl. LULUCF | | | | | | | 65 514 |

Table 1.2 Danish emissions of other air pollutants in 2007 as reported to CLRTAP (Nielsen et al., 2009b).

| Sector | $NO_x$ Gg | CO Gg | NMVOC Gg | $SO_x$ Gg | $NH_3$ Gg | TSP Mg | $PM_{10}$ Mg | $PM_{2.5}$ Mg |
|---|---|---|---|---|---|---|---|---|
| Energy | 167 | 448 | 74 | 23 | 2 | 37 723 | 34 091 | 31 062 |
| Industrial Processes | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Solvent and Other Product Use | - | - | 28 | - | - | - | - | - |
| Agriculture | - | - | 0 | - | 67 | 14 562 | 9 326 | 1 673 |
| Land Use, Land-Use Change and Forestry | - | - | - | - | - | - | - | - |
| Waste | 0 | 0 | 0 | 0 | | 2 | 2 | 2 |
| Total | 167 | 448 | 103 | 23 | 70 | 52 287 | 43 419 | 32 737 |

Table 1.3 Danish emissions of other air pollutants in 2007 as reported to CLRTAP (Nielsen et al., 2009b).

| Sector | Pb Mg | Cd Mg | Hg Mg | As Mg | Cr Mg | Cu Mg | Ni Mg | Se Mg | Zn Mg |
|---|---|---|---|---|---|---|---|---|---|
| Energy | 6.10 | 0.74 | 1.07 | 0.00 | 0.63 | 1.36 | 9.94 | 8.73 | 1.99 |
| Industrial Processes | 0.07 | 0.00 | 0.00 | - | 0.00 | 0.00 | 0.05 | | 0.00 |
| Solvent and Other Product Use | - | - | - | - | - | - | - | - | - |
| Agriculture | - | - | - | - | - | - | - | - | - |
| Land Use, Land-Use Change and Forestry | - | - | - | - | - | - | - | - | - |
| Waste | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 6.17 | 0.74 | 1.11 | 0.00 | 0.63 | 1.36 | 9.99 | 8.73 | 1.99 |

Table 1.4 Danish emissions of other air pollutants in 2007 as reported to CLRTAP (Nielsen et al., 2009b).

| Sector | Dioxin g I-Teq | Benzo(a) pyrene Mg | Benzo(b) fluoranthene Mg | Benzo(k) fluoranthene Mg | Indeno(1,2,3-cd)pyrene Mg | HCB Kg |
|---|---|---|---|---|---|---|
| Energy | 21.67 | 5.06 | 5.42 | 3.00 | 3.62 | - |
| Industrial Processes | 0.02 | - | - | - | - | - |
| Solvent and Other Product Use | - | - | - | - | - | - |
| Agriculture | - | - | - | - | - | - |
| Land Use, Land-Use Change and Forestry | - | | | | | - |
| Waste | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | - |
| Total | 21.73 | 5.06 | 5.42 | 3.00 | 3.62 | - |

The reporting to the Kyoto Protocol in 2009 includes emissions for the years 1990-2007. In Table 1.5 the net emission is given for each year with the changes compared to the base year. In 2007 the Danish emissions has been reduced by 4 % compared to the base year. Projected

emissions for the period 2008-2012 indicate that Denmark will reduce its emissions by approximately 4 % in 2008-2012. The remaining part of the Danish reduction obligation will be achieved by means of the flexible mechanisms in the Kyoto Protocol covering sinks, trade of $CO_2$ quota and emission reducing projects in other countries (JI and CDM projects).

Table 1.5 Trends for the Danish greenhouse gas emissions from base year to 2007.

| | Base year* | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Emission and removals, $10^6$ tonnes $CO_2$-equivalents | 69.3 | 69.1 | 79.6 | 73.5 | 75.8 | 79.2 | 76.2 | 89.5 | 79.8 | 75.6 | 72.6 |
| Changes compared to base year, $10^6$ tonnes $CO_2$-equivalents | | -0.3 | 10.3 | 4.1 | 6.5 | 9.9 | 6.9 | 20.2 | 10.5 | 6.3 | 3.2 |
| Changes compared to base year, % | | -0.4 | 14.9 | 6.0 | 9.3 | 14.3 | 10.0 | 29.1 | 15.1 | 9.1 | 4.7 |
| *Continued* | | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | | |
| Emission and removals, $10^6$ tonnes $CO_2$-equivalents | | 68.0 | 69.4 | 68.6 | 73.7 | 67.8 | 63.5 | 71.0 | 66.6 | | |
| Changes compared to base year, $10^6$ tonnes $CO_2$-equivalents | | -1.4 | 0.1 | -0.7 | 4.4 | -1.6 | -5.8 | 1.7 | -2.7 | | |
| Changes compared to base year, % | | -2.0 | 0.1 | -1.0 | 6.3 | -2.3 | -8.4 | 2.5 | -3.9 | | |

* The base year emission is the sum of emissions of $CO_2$, $CH_4$ and $N_2O$ in 1990 and the emission of F-gasses in 1995 in accordance with the Kyoto Protocol.

The objective of the Gothenburg Protocol, which is a protocol under the UNECE CLRTAP, is to reduce emissions of $SO_2$, $NO_x$, NMVOC and $NH_3$. The protocol does not include reduction targets. Instead emission ceilings for 2010 have been defined. These have also been adopted in the EU (EU Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001) according to the knowledge about critical loads and environmental impacts on the ecosystem. The emission ceilings are listed in Table 1.6 with the Danish emissions for 2007. In 2007 Denmark's emission of $SO_2$ was below the emission ceilings while the emissions of $NO_x$, NMVOC and $NH_3$ have to be reduced before 2010.

Table 1.6 Emission ceilings under the UNECE CLRTAP and the Danish emissions of $SO_2$, $NO_x$, NMVOC and $NH_3$ in 2007.

| | $SO_2$ | $NO_x$ | NMVOC | $NH_3$* |
|---|---|---|---|---|
| | tonnes | tonnes | tonnes | tonnes |
| Emission ceiling | 55 000 | 127 000 | 85 000 | 69 000 |
| Emission 2007 | 23327 | 166 707 | 104 389 | 69 746 |

*The $NH_3$ emission ceiling is excluding emissions from straw treatment and crops.

# 2 Fugitive emissions to the air

The total Danish GHG emission in year 2007 was 66 641 Gg $CO_2$ equivalents ($CO_2$ eqv.) excluding Land use, Land use change and forestry (LULUCF) and 65 514 Gg $CO_2$ eqv. including LULUCF.

"Fugitive emissions from fuels" is a subsector under the energy sector which accounts for approximately 1 % of the GHG emissions in the energy sector as a whole. The majority of the GHG emissions in the energy sector stem from fuel combustion in energy industries and transport. Fugitive emissions from fuels owe to extraction, handling, storage, transmission and distribution of solid and liquid fuels. Also, flaring is an important source for fugitive emissions from fuels. Among the facilities that contribute to the fugitive emissions are the processing facilities in the North Sea, gas storage and treatment plants, refineries and filling stations. Furthermore, transmission pipelines and distribution networks are important sources.

The total fugitive GHG emission was 496 Gg $CO_2$ eqv. in 2007, thereby accounting for 0.75 % of the total Danish GHG emission excluding LULUCF. Fugitive emissions do not include emissions of the F-gasses HFCs, PFCs and $SF_6$ and therefore the total fugitive GHG emission, expressed as $CO_2$ eqv., refers to the sum of $CO_2$, $CH_4$ and $N_2O$ emissions.

Flaring is the only source of $CO_2$ in the fugitive sector. The $CO_2$ emission make up 74 % of the total GHG emission in the fugitive sector, which corresponds well to the percentage of $CO_2$ of the national total net (including LULUCF) GHG emission (80 %) (Figure 2.1).

The major sources of fugitive emissions of $CH_4$ are extraction of oil and gas, refining of oil, transport of oil in pipelines and loading of oil onto ships. The share of $CH_4$ of the total fugitive emissions is much bigger than of the share of the national total, namely 26 % versus 9 %. The largest contribution to the fugitive $CH_4$ emission is emissions from transportation of oil in pipelines and fugitive emissions from extraction of oil and natural gas at the platforms in the North Sea.

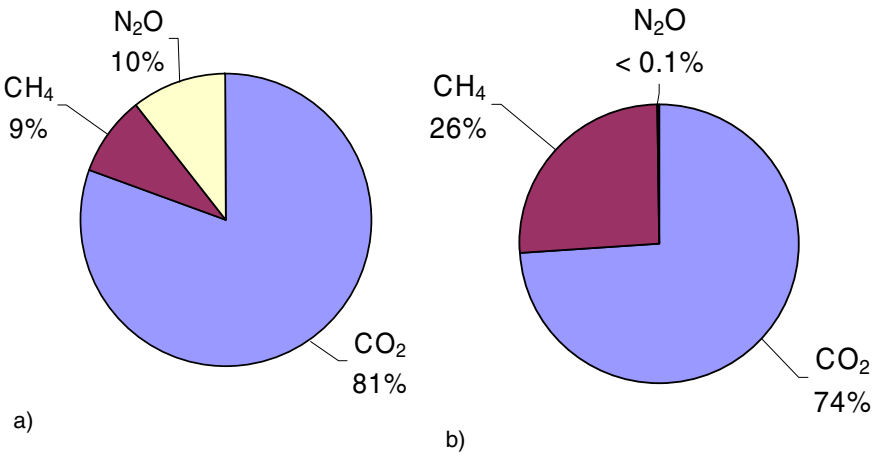


Figure 2.1 Distribution of the emission of green house gasses for a) the national emission and b) the fugitive emission in Denmark in 2007.

To give an impression of the quantities of the GHG emissions on both national and sector level, the emissions of $CO_2$, $CH_4$ and $N_2O$ is given in Table 2.1 as well as the total GHG emission. The emissions are given in Gg and in $CO_2$ eqv. Furthermore, the percentage of the national total is included in Figure 2.1.

Table 2.1 Emissions of greenhouse gasses in the fugitive sector, the energy sector and the national total gross emission in Gg for the gasses separately and in $CO_2$ eqv. for the sum of GHG.

| | $CO_2$ | $CH_4$ | $N_2O$ | GHG |
|---|---|---|---|---|
| | Gg | Gg | Gg | Gg $CO_2$ eqv. |
| Fugitive emissions from fuels (1B) | 367 | 6 | 0 | 496 |
| Energy (1) | 51 494 | 28 | 1 | 52 546 |
| National total brutto emission * | 58 069 | 268 | 21 | 66 641 |

*excluding LULUCF

Beside the greenhouse gasses also $NO_x$, CO, NMVOC, $SO_2$, dioxin, fluoranthene and particles are included in the inventory of fugitive emissions. Flaring offshore and in the refineries is the only source to fugitive $SO_2$, $N_2O$, $NO_x$, dioxin, fluoranthene and CO. The fugitive emissions of NMVOC originate for the major part from extraction, loading of ships, transmission and distribution of oil and to a much lesser degree from natural gas and fugitive emissions from filling stations. The emission of PM comes from storage of solid fuels (coal piles) and to a minor degree from flaring offshore and in refineries. Particulate emission is estimated in three fractions; total suspended particulate matter (TSP) and particles with an aerodynamic diameter less than 10µm ($PM_{10}$) and less than 2.5 µm ($PM_{2.5}$).

The fugitive sector's and the energy sector's share of the national emissions of $NO_x$, CO, NMVOC, $SO_2$, $PM_{10}$ and $PM_{2.5}$ are shown in Table 2.2. The fugitive sector is an important source of NMVOC and $SO_2$. The main sources for NMVOC in the fugitive sector are onshore and offshore loading (30 %) and transport of oil in pipelines and storage of raw oil in tanks (30 %) contributing with 7.5 Gg NMVOC. The major part of fugitive $SO_2$ stems from sulphur recovery and flaring in refineries.

The major source of emission of particles in the fugitive sector is dust from storage of coal. It must be noted that the $CH_4$ emission from post-

mining of coal (storage and transport) should be accounted for in the emission inventory of the mining countries according to the IPCC Good Practice Guidance and is therefore not included in the Danish emission inventory.

The fugitive sector has only minor emissions of $NO_x$, CO, $SO_2$ and PM compared to the total Danish emissions of these components (Table 2.3).

Table 2.2 Emissions of air pollutants in the fugitive sector, the energy sector and the national total gross emission in g I-Teq. for dioxin and Gg for the remaining components.

| | $NO_x$ | CO | NMVOC | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | Dioxin |
|---|---|---|---|---|---|---|---|
| | | | Gg | | | | g I-Teq |
| Fugitive emissions from fuels (1 B) | 0.2 | 0.2 | 13.3 | 1.1 | 0.5 | 0.1 | < 0.1 |
| Energy (1) | 167 | 448 | 74 | 23 | 34 | 31 | 22 |
| National total brutto emission * | 167 | 448 | 103 | 23 | 43 | 33 | 28 |

*excluding LULUCF

Table 2.3 Share of national total emissions for air pollutants in the fugitive sector and in the energy sector.

| | $NO_x$ | CO | NMVOC | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | Dioxin |
|---|---|---|---|---|---|---|---|
| | | | % of national total emission* | | | | |
| Fugitive emissions from fuels (1 B) | 0.1 | < 0.1 | 12.9 | 4.9 | 1.1 | 0.2 | < 0.1 |
| Energy (1) | 100 | 100 | 72 | 100 | 79 | 95 | 78 |

*excluding LULUCF

# 3 Methodology

According to the IPCC sector definitions the category *fugitive emissions* is a sub-category under the main-category Energy (Sector 1). The category *fugitive emissions* (Sector 1B) is segmented into sub-categories covering emissions from solid fuels (coal mining and handling (1B1a), solid fuel transformation (1B1b), other (1B1c)) and from oil and natural gas (oil (1B2a), natural gas (1B2b), venting and flaring (1B2c) and other (1B2d)). The sub-sectors relevant for the Danish emission inventory are shortly described below according to Danish conditions:

- 1B1c Fugitive emission from solid fuels: Emissions from solid fuels are only relevant for the Danish national emission inventories in the case of particulate emissions. Other components are not occurring, as these emissions should be included in the inventory for the nation housing the coalmines.
- 1B2a Fugitive emissions from oil includes emissions from offshore activities and refineries.
- 1B2b Fugitive emissions from natural gas includes emissions from transmission and distribution of natural gas. Emissions from gas storage are included in the transmission.
- 1B2c Venting and flaring includes both offshore flaring, flaring in gas storage and treatment plants and in refineries. In Denmark venting of gas is assumed to be negligible as controlled venting enters the gas flare system.

Activity data, emission factors and emissions are stored in the Danish emission database on SNAP sector categories (Selected Nomenclature for Air Pollution). In Table 3.1 the corresponding SNAP codes and IPCC sectors relevant to fugitive emissions are shown. Further, the table holds the SNAP names for the SNAP codes and the overall activity (e.g. oil and natural gas)

Table 3.1 Overview of the SNAP codes and the corresponding IPCC sources relevant for fugitive emissions.

| SNAP code | SNAP name | IPCC sector | Activity |
|---|---|---|---|
| 04 | Production processes | | |
| 0401 | Processes in petroleum industries | | |
| 040101 | Petroleum products processing | 1 B 2 a 4 | Oil |
| 040103 | Other | 1 B 2 a 4 | Oil |
| 0402 | Processes in iron and steel industries and collieries | | |
| 040201 | Coke oven (door leakage and extinction) | | |
| 040204 | Solid smokeless fuel | | |
| 05 | Extraction and distribution of fossil fuels and geothermal energy | | |
| 0501 | Extraction and 1st treatment of solid fossil fuels | | |
| 050101 | Open cast mining | | |
| 050103 | Storage of solid fuel | 1 B 1 a | Coal mining and handling |
| 0502 | Extraction, 1st treatment and loading of liquid fossil fuels | | |
| 050201 | Land-based activities | 1 B 2 a 2 | Oil |
| 050202 | Off-shore activities | 1 B 2 a 2 | Oil |
| 0503 | Extraction, 1st treatment and loading of gaseous fossil fuels | | |
| 050301 | Land-based desulfuration | | |
| 050303 | Off-shore activities | 1 B 2 b | Natural gas |
| 0504 | Liquid fuel distribution (except petrol distribution) | | |
| 050401 | Marine terminals (tankers, handling and storage) | | |
| 050402 | Other handling and storage (including pipeline) | | |
| 0505 | Petrol distribution | | |
| 050501 | Refinery dispatch station | | |
| 050503 | Filling stations (including refuelling of cars) | 1 B 2 a 5 | Oil |
| 0506 | Gas distribution networks | | |
| 050601 | Pipelines | 1 B 2 b / 1 B 2 b 3 | Natural gas / Transmission |
| 050602 | Distribution networks | 1 B 2 b / 1 B 2 b 4 | Natural gas / Distribution |
| 09 | Waste treatment and disposal | | |
| 0902 | Waste incineration | | |
| 090203 | Flaring in oil refinery | 1 B 2 c 2 1 | Venting and flaring |
| 090206 | Flaring in oil and gas extraction | 1 B 2 c 2 2 | Venting and flaring |

IPCC sector and activity is only given for categories included in the Danish emission inventory.

Table 3.1 summarizes the Danish fugitive emissions in 2007. The methodologies, activity data and emission factors used for calculation are described in the following chapters.

Table 3.1 Summary of the Danish fugitive emissions in 2007. P refers to point source and A refers to area source.

| IPCC category | SNAP code | Source | Pollutant | Emission, tonnes |
|---|---|---|---|---|
| 1B2a iv | 040101 | P | $SO_2$ | 0.00 * |
| 1B2a iv | 040101 | P | NMVOC | 3773.03 |
| 1B2a iv | 040101 | P | $CH_4$ | 2115.63 |
| 1B2a iv | 040103 | P | $SO_2$ | 609.70 |
| 1B1a | 050103 | A | TSP | 1218.48 |
| 1B1a | 050103 | A | $PM_{10}$ | 487.39 |
| 1B1a | 050103 | A | $PM_{2.5}$ | 48.74 |
| 1B2a i | 050201 | A | NMVOC | 5981.00 |
| 1B2a i | 050201 | A | $CH_4$ | 1883.00 |
| 1B2a i | 050202 | A | NMVOC | 2442.00 |
| 1B2a i | 050202 | A | $CH_4$ | 1839.00 |
| 1B2a v | 050503 | A | NMVOC | 968.59 |
| 1B2b | 050601 | A | NMVOC | 2.26 |
| 1B2b | 050601 | A | $CH_4$ | 7.40 |
| 1B2b | 050601 | P | NMVOC | 18.00 |
| 1B2b | 050601 | P | $CH_4$ | 71.00 |
| 1B2b | 050603 | A | NMVOC | 26.78 |
| 1B2b | 050603 | A | $CH_4$ | 87.83 |
| 1B2c | 090203 | P | $SO_2$ | 525.60 |
| 1B2c | 090203 | P | $NO_x$ | 22.39 |
| 1B2c | 090203 | P | NMVOC | 28.39 |
| 1B2c | 090203 | P | $CH_4$ | 52.71 |
| 1B2c | 090203 | P | CO | 4.73 |
| 1B2c | 090203 | P | $CO_2$ | 19.60 |
| 1B2c | 090203 | P | $N_2O$ | 0.34 |
| 1B2c | 090203 | P | TSP | 1.72 |
| 1B2c | 090203 | P | $PM_{10}$ | 1.72 |
| 1B2c | 090203 | P | $PM_{2.5}$ | 1.72 |
| 1B2c | 090203 | P | dioxin | <0.01 |
| 1B2c | 090206 | A | $SO_2$ | 1.81 |
| 1B2c | 090206 | A | $NO_x$ | 187.08 |
| 1B2c | 090206 | A | NMVOC | 14.45 |
| 1B2c | 090206 | A | $CH_4$ | 28.89 |
| 1B2c | 090206 | A | CO | 144.48 |
| 1B2c | 090206 | A | $CO_2$ | 342.58 |
| 1B2c | 090206 | A | $N_2O$ | 2.89 |
| 1B2c | 090206 | A | TSP | 0.60 |
| 1B2c | 090206 | A | $PM_{10}$ | 0.60 |
| 1B2c | 090206 | A | $PM_{2.5}$ | 0.60 |
| 1B2c | 090206 | A | dioxin | <0.01 |
| 1B2c | 090206 | A | fluoranthene | 0.13 |
| 1B2c | 090206 | P | $SO_2$ | 0.02 |
| 1B2c | 090206 | P | $NO_x$ | 7.65 |
| 1B2c | 090206 | P | NMVOC | 7.04 |
| 1B2c | 090206 | P | $CH_4$ | 25.07 |
| 1B2c | 090206 | P | CO | 15.70 |
| 1B2c | 090206 | P | $CO_2$ | 4.46 |
| 1B2c | 090206 | P | $N_2O$ | 0.08 |
| 1B2c | 090206 | P | TSP | 0.01 |
| 1B2c | 090206 | P | $PM_{10}$ | 0.01 |
| 1B2c | 090206 | P | $PM_{2.5}$ | 0.01 |
| 1B2c | 090206 | P | dioxin | <0.01 |
| 1B2c | 090206 | P | fluoranthene | <0.01 |

* From 2001 $SO_2$ emissions from oil refining are included in stationary combustion.

## 3.1 Methods of calculation

The following chapters give descriptions on the methods of calculation used in the Danish emission inventory. Further, the activity data and emission factors that form the basis for the calculations are described according to data source and values.

### 3.1.1 Fugitive emissions from solid fuels

The emissions of PM from storage of coal are estimated on the basis of the imported amount of coal (equation 6.1).

Equation 6.1: $$E_{coal\_storage} = EMF_{coal\_storage} \cdot I_{coal}$$

where $EMF_{coal\_storage}$ is the emission factor for storage of coal in coal piles and $I_{coal}$ is the amount of coal imported in the actual year.

### 3.1.2 Fugitive emissions from oil

The emissions from oil derive from offshore activities, filling stations and refineries. Emissions from offshore activities include emissions from extraction, onshore oil tanks and onshore and offshore loading of ships. In the case of filling stations emissions from reloading of tankers and refuelling of vehicles are included. The emissions from refineries derive from petroleum products processing (oil refining). Emissions from flaring in refineries are included in the chapters concerning flaring (Chapter 3.1.4, 3.2.6, 3.3.6 and 3.4.6).

#### Offshore and onshore activities

Fugitive emissions from oil include emissions from offshore extraction, from onshore oil tanks and from onshore and offshore loading of ships.

The total emission can be expressed as:

Equation 6.2: $$E_{total} = E_{extraction} + E_{ship} + E_{oil\ tanks}$$

#### Fugitive emissions from extraction

According to the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007) the total fugitive emissions of volatile organic components (VOC) from extraction of oil and gas can be estimated by means of equation 6.3.

Equation 6.3: $$E_{extraction,VOC} = 40.2 \cdot N_P + 1.1 \cdot 10^{-2} P_{gas} + 8.5 \cdot 10^{-6} \cdot P_{oil}$$

where $N_P$ is the number of platforms, $P_{gas}$ is the production of gas, $10^6$ $Nm^3$ and $P_{oil}$ is the production of oil, $10^6$ tons.

It is assumed that the VOC contains 75 % methane ($CH_4$) and 25 % NMVOC and in consequence the total emission of $CH_4$ and NMVOC for extraction of oil and gas can be calculated as:

Equation 6.4: $E_{extraction,CH_4} = 0.75 \cdot E_{extraction,VOC}$

Equation 6.5: $E_{extraction,NMVOC} = 0.25 \cdot E_{extraction,VOC}$

#### Loading of ships

Fugitive emissions of $CH_4$ and NMVOC from loading of ships include the transfer of oil from storage tanks or directly from the well into ships. The activity also includes losses during transport. When oil is loaded hydrocarbon vapour will be displaced by oil and new vapour will be formed, both leading to emissions. The emissions from ships are calculated by equation 6.6.

Equation 6.6: $E_{ships} = EMF_{ships,onshore} \cdot L_{oil,onshore} + EMF_{ships,offshore} \cdot L_{oil,ofshore}$

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

#### Oil tanks

The $CH_4$ and NMVOC emissions for storage of oil are given in the green accounts from DONG Energy for 2007 (DONG Energy, 2008). An implied emission factor is calculated for use in the CRF tables on the basis of the amount of oil transported in pipelines according to equation 6.7.

Equation 6.7: $IEF_{tanks} = \frac{E_{tanks}}{T_{oil}}$

where $IMF_{tanks}$ is the implied emission factor for storage of raw oil in tanks, $E_{tanks}$ is the emission and $T_{oil}$ is the amount of oil transported in pipelines.

#### Filling stations

NMVOC emissions from filling stations are estimated as outlined in equation 6.8.

Equation 6.8: $E_{filling\ stations} = \left(EMF_{reloading} \cdot T_{fuel}\right) + \left(EMF_{refuelling} \cdot T_{fuel}\right)$

where $EMF_{reloading}$ is the emission factor for reloading of tankers to storage tanks at the filling stations, $EMF_{refuelling}$ is the emission factor for refuelling of vehicles and $T_{fuel}$ is the amount of gasoline used for road transport.

#### Oil refining

When oil is processed in the refineries, part of the volatile organic components hydrides (VOC) are emitted to the atmosphere. The VOC emissions from the petroleum refinery process include non-combustion emissions from handling and storage of feedstock (raw oil), from the petroleum product processing and from handling and storage of products. Emissions from flaring in refineries are included under "Flaring". In cases where only the total VOC emission is given

by the refinery the emission of $CH_4$ and NMVOC is estimated due to the assumption that 1 % of VOC is $CH_4$ and the remaining 99 % is NMVOC.

Both the non-combustion processes including product processing and sulphur recovery plants emit $SO_2$. The $SO_2$ emissions are calculated by the refineries and implemented in the emission inventory without further calculation.

### 3.1.3 Fugitive emissions from gas

#### Transmission and distribution of gas

The fugitive emission from transmission, storage and distribution is based on information from the gas companies. The only calculation added to the delivered data is estimation of NMVOC due to the gas quality measured by Energinet.dk.

### 3.1.4 Flaring

Emissions from flaring are estimated from the amount of gas flared offshore, in gas treatment/storage plants and in refineries and from the corresponding emission factors. Offshore flaring amounts are given in Denmark's oil and gas production (Danish Energy Agency, 2008b) while flaring in treatment/storage plants are given in DONG Energy's green accounts (Dong Energy, 2008). The emission factors for flaring are based on the EMEP/CORINAIR Guidebook 2007 and the calorific value for natural gas in Denmark that again is based on measurements in quality measuring station. $SO_2$ and $NO_x$ emissions from flaring in refineries are given in the data set delivered by the individual refineries.

## 3.2 Activity data

### 3.2.1 Coal Storage

The activity data is the imported amount of coal and the calorific values of coal (Danish Energy Agency, 2008c). In 2007 the imported amount was 8 123 Gg (Figure 3.1).

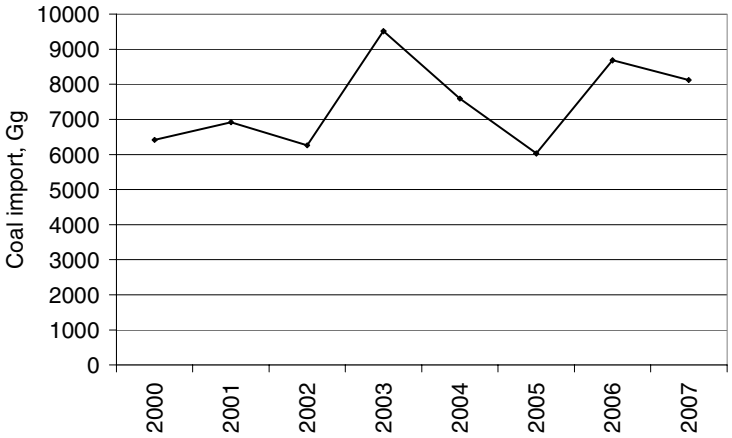

Figure 3.1 Amounts of imported coal.

### 3.2.2 Extraction of oil and gas and loading of ships

Activity data used in the calculations of the emissions from oil and gas production and loading of ships are shown in Table 3.3. Data are based on information from the Danish Energy Agency (2008b) and from the green accounts from DONG Energy (DONG Energy, 2008).

Table 3.3 Activity data for 2007.

| Activity | Symbols | Amounts | Data source |
|---|---|---|---|
| Number of platforms | $N_p$ | 55 | Danish Energy Agency, 2008b |
| Produced gas, $10^6$ $Nm^3$ | $P_{gas}$ | 10 046 | Danish Energy Agency, 2008b |
| Produced oil, $10^3$ $m^3$ | $P_{oil,vol}$ | 18 083 | Danish Energy Agency, 2008b |
| Produced oil, $10^3$ tonnes | $P_{oil}$ | 15 551 | Danish Energy Agency, 2008b |
| Oil loaded, $10^3$ $m^3$ | $L_{oil\ off\text{-}shore}$ | 2 163 | Danish Energy Agency, 2008b |
| Oil loaded, $10^3$ tonnes | $L_{oil\ off\text{-}shore}$ | 1 860 | Danish Energy Agency, 2008b |
| Oil loaded, $10^3$ $m^3$ | $L_{oil\ on\text{-}shore}$ | 12 000 | DONG Energy, 2008 |
| Oil loaded, $10^3$ tonnes | $L_{oil\ on\text{-}shore}$ | 10 320 | DONG Energy, 2008 |

Mass weight raw oil = 0.86 ton/$m^3$.

As seen in Figure 3.2 the production of oil and gas in the North Sea have generally increased in the years 1990-2004. Since 2004 the production has decreased. The number of platforms is yet still increasing (Figure 3.3). Five major platforms were completed in 1997-1999, which is the main reason for the great increase in the oil production in the years 1998-2000.

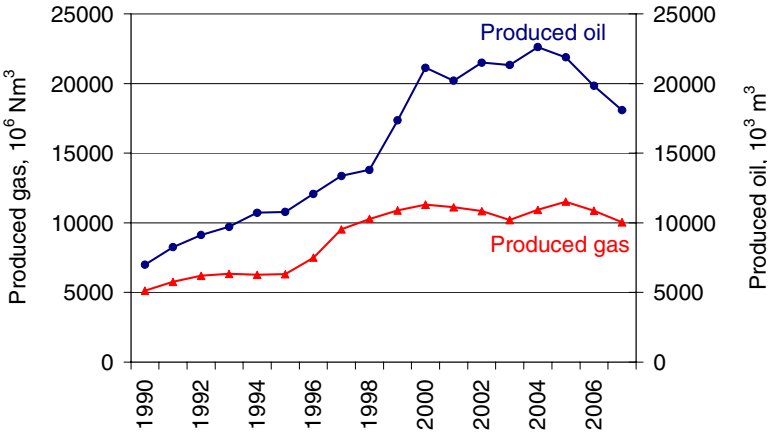


Figure 3.2 Production of oil and gas in the Danish part of the North Sea.

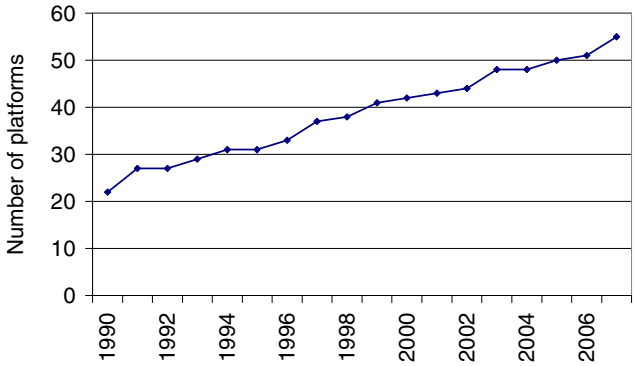


Figure 3.3 The number of platforms in the Danish part of the North Sea.

The amounts of oil loaded offshore on ships roughly follow the trend of the oil and gas production (Figure 3.4). Data for offshore loading is not available until 1999. In case of onshore loading of ships the trend is more smoothed.

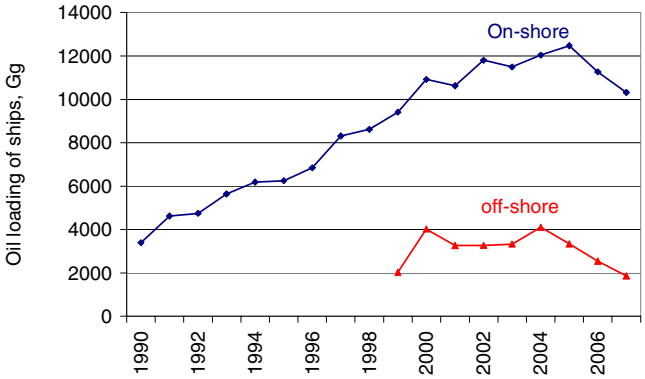


Figure 3.4 Onshore and offshore loading of ships.

### 3.2.3 Oil refining

Data on the amount of crude oil processed in the two Danish refineries are given by the refineries in their annual green account and data are shown in Table 3.4. In the last years the amount of crude oil being processed has been slightly decreasing to 7 963 Gg in 2007.

Table 3.4 Oil refineries. Processed crude oil in the two Danish refineries.

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| Crude oil, 1000 Mg | 7 263 | 7 798 | 8 232 | 8 356 | 8 910 | 9 802 | 10 522 | 7 910 | 7 906 | 8 106 |
| *Continued* | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | | |
| Crude oil, 1000 Mg | 8 406 | 8 284 | 8 045 | 8 350 | 8 264 | 8 033 | 8 179 | 7 963 | | |

### 3.2.4 Filling stations

The Danish Energy statistics holds data on the sale of gasoline that is the basis for estimating emissions of NMVOC from filling stations. The gasoline sales show an increase from 1990-1998 and a slightly decreasing trend from 1999-2007 as shown in Figure 3.5. In 2007 the gasoline sale was 1 817 240 Mg.

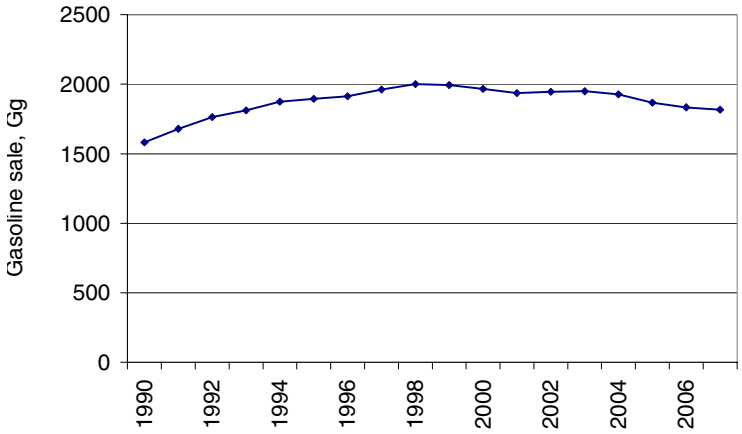


Figure 3.5 Gasoline sales in Denmark 1990-2007.

### 3.2.5 Transmission, storage and distribution of gas

The activity data used in the calculation of the emissions from natural gas is shown in Table 3.5. Transmissions rates for 1990-1997 refer to the Danish energy statistics and to the annual environmental report of DONG Energy for 1998. The distribution rates for 1990-1998 are estimated according to the transmission rates. Transmissions and distribution rates for 1999-2006 refers to Dong Energy, Danish Gas Technology Centre and the Danish gas distribution companies. In 2007 the transmission rate stems from the annual environmental report by Energinet.dk and the distribution rate is estimated according to the 2007 transmission rate and the rate between transmission and distribution in 2006.

Table 3.5 Activity data on transmission and distribution of gas.

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| Transmission, $Mm^3$ * | 2 739 | 3 496 | 3 616 | 3 992 | 4 321 | 4 689 | 5 705 | 6 956 | 6 641 | 6 795 |
| Distribution, $Mm^3$ ** | 1 574 | 1 814 | 1 921 | 2 185 | 2 362 | 2 758 | 3 254 | 3 276 | 3 403 | 3 297 |
| *Continued* | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | | |
| Transmission, $Mm^3$ * | 7 079 | 7 289 | 7 287 | 7 275 | 7 384 | 7 600 | 7 600 | 6 400 | | |
| Distribution, $Mm^3$ ** | 3 181 | 3 675 | 3 420 | 3 420 | 3 248 | 2 983 | 3 319 | 3 022 | | |

* In 1990-1997 transmission rates refer to Danish energy statistics, in 1998 the transmission rate refers to the annual environmental report of DONG Energy, in 1999-2006 emissions refer to DONG/Danish Gas Technology Centre (Karll 2003, Karll 2005, Oertenblad 2006, Oertenblad 2007). In 2007 transmission data refers to the annual environmental report 2008 by Energinet.dk.

**) In 1990-98 distribution rates are estimated from the Danish energy statistics. Distribution rates are assumed to equal total Danish consumption rate minus the consumption rates of sectors that receive the gas at high pressure. The following consumers are assumed to receive high pressure gas: town gas production companies, production platforms and power plants. In 1999-2006 distribution rates refer to DONG Energy / Danish Gas Technology Centre / Danish gas distribution companies (Karll 2003, Karll 2005, Oertenblad 2006, Oertenblad 2007), In 2007 distributions data is estimated according to 2006 and the rate between transmission in 2006 and the transmission rate for 2007.

In 2007 the gas transmission was 6 400 $Mm^3$ and the distribution is estimated to 3 022 $Mm^3$ (Figure 3.6). This is a decrease compared to 2006 owing to a mild winter and because Denmark had import of electricity from Norway and Sweden.

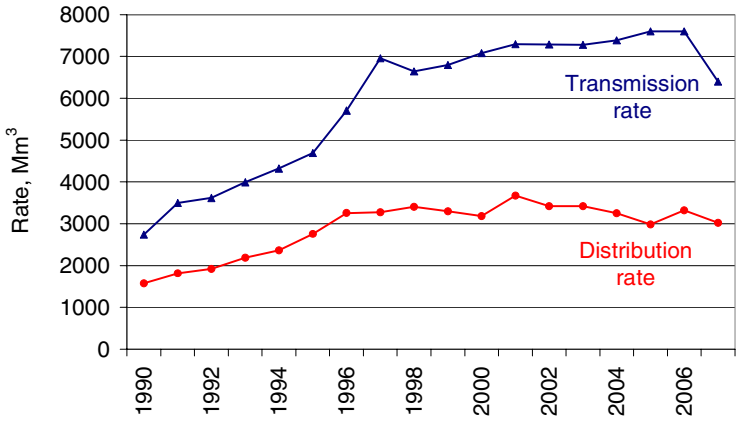


Figure 3.6 Transmission and distribution rates of gas.

Data on the transmission pipelines excluding offshore pipelines and on the distribution network are given by DGC and Energinet.dk concerning length and material. In 2007 the length of the transmission pipelines was 860 km. Because the distribution system in Denmark is relatively new most of the distribution network is made of PE. In 2007 the length of the distribution network was 18 959 km of which 0 km was made of cast iron, 1 896 km was made of steel and 17 063 km made of plastic (PE). For this reason the fugitive emission is negligible under normal circumstances as the PE distribution system is basically tight with only minimal fugitive losses. However, the PE pipes are vulnerable and therefore most of the fugitive emissions from the pipes are caused by losses due to excavation damages and construction and maintenance activities performed by the gas companies. These losses are either measured or estimated by calculation in each case by the gas companies.

In Denmark there are two natural gas storage facilities. Both are obligated to make a green account on annual basis. Data on gas input and

withdrawal are included and were 746 $Mm^3$ and 581 $Mm^3$ in 2007, respectively. Until 2000 emissions from storage of gas were included in transmission in the inventories.

### 3.2.6 Flaring

The flaring rates are shown in Table 3.6. Flaring rates in gas treatment and gas storage plants are not available until 1995. The mean value for flaring in treatment and storage facilities for the following ten years (1995 to 2004) has been adopted as basis for the emission calculation for the years 1990-1994.

The amount of flared gas is high in 2007 because of larger maintenance work at the gas treatment plant. The flared amount is 1 972 491 $Nm^3$ in 2007 in contrast to 975 071 $Nm^3$ in 2006.

The offshore flaring amounts have been decreasing over the last four years in accordance with the decrease in production as seen in Figure 3.2.

Table 3.6 Natural gas flaring rate (Danish Energy Agency, 2008c; DONG Energy, 2008).

| Year | Flaring, offshore, TJ | Flaring, treatment and storage, TJ |
|---|---|---|
| 1990 | 4 275 | 35 |
| 1991 | 8 827 | 35 |
| 1992 | 9 105 | 35 |
| 1993 | 7 877 | 35 |
| 1994 | 7 759 | 35 |
| 1995 | 6 017 | 45 |
| 1996 | 6 650 | 30 |
| 1997 | 9 619 | 35 |
| 1998 | 7 007 | 30 |
| 1999 | 15 280 | 32 |
| 2000 | 9 896 | 29 |
| 2001 | 10 688 | 35 |
| 2002 | 8 788 | 43 |
| 2003 | 9 105 | 32 |
| 2004 | 10 371 | 34 |
| 2005 | 7 323 | 42 |
| 2006 | 7 165 | 39 |
| 2007 | 6 096 | 79 |

## 3.3 Emission factors

### 3.3.1 Coal storage

Emissions of PM from coal storage are estimated by the emission factors used in the emission inventory of Poland (Olendry´nski et al., 2004). The emission factors are listed in Table 3.7.

Table 3.7 Emission factors used to estimate particulate emissions from coal storage.

| Emission factor | TSP | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|
| Emission factor, g pr Mg | 150 | 60 | 6 |

### 3.3.2 Loading of ships

In the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007) standard emission factors for different countries are given. In the Danish emission inventory the Norwegian emission factors are used for estimation of fugitive emissions from loading of ships onshore and offshore (EMEP/CORINAIR, 2007, Table 8.15). The emission factors are listed in Table 3.8.

Table 3.8 Emission factors for loading of ships onshore and offshore.

| | NMVOC, fraction of loaded | Reference |
|---|---|---|
| Ships off-shore | 0.001 | EMEP/CORINAIR, 2007 |
| Ships on-shore | 0.0002 | EMEP/CORINAIR, 2007 |

### 3.3.3 Oil refining

The refineries deliver information on consumption of fuel gas and fuel oil. The calorific values given by the refineries are used when available. When not available standard calorific values given in the basic data tables from the Danish Energy Agency combined with the conversion factor between fuel gas and fuel oil given by the refinery are used for calculation.

The emissions are given for $SO_2$, $NO_x$ and VOC. Before 2004 the VOC emissions were not split in $CH_4$ and NMVOC. The assumption that 1 % of the VOC emission is $CH_4$ and the remaining 99 % is NMVOC is adapted for the years before 2004.

### 3.3.4 Filling stations

NMVOC from filling stations is calculated by use of different emission factors for the time series as shown in Table 3.9. In 1994 the emission factors for NMVOC from filling stations were investigated by Fenhann and Kilde (1994) for the years 1990 1991 and 1992, individually. The emission factors reported for reloading and refuelling for 1990 were used for the years 1985-1990, while the emission factors for 1991 was used for that year only. For the years 1992-1995 only emission factor for refuelling reported by Fenhann and Kilde (1994) was used in the Danish emission inventory. For Reloading of tankers the British emission factor was adopted for the years 1992-2007. For the years 1996-1999 emission factors for the sum of reloading and refuelling have been estimated using interpolation between 1995 and 2000.

Table 3.9 Emission factors used for estimating NMVOC from filling stations.

| EMF NMVOC | Reloading of tankers, kg NMVOC pr tonnes gasoline | Refuelling of vehicles, kg NMVOC pr tonnes gasoline | Sum of reloading and refuelling, kg NMVOC pr tonnes gasoline | Source |
|---|---|---|---|---|
| 1985-1990 | 1.28 | 1.52 | 2.80 | Fennmann & Kilde,1994 |
| 1991 | 0.64 | 1.52 | 2.16 | Fennmann & Kilde,1994 |
| 1992-1995 | 0.08 | 1.52 | 1.60 | GB EMF, Fennmann & Kilde,1994 |
| 1996 | | | 1.38 | Interpolation between 1995 and 2000 |
| 1997 | | | 1.17 | Interpolation between 1995 and 2000 |
| 1998 | | | 0.96 | Interpolation between 1995 and 2000 |
| 1999 | | | 0.75 | Interpolation between 1995 and 2000 |
| 2000-2007 | 0.08 | 0.46 | 0.53 | GB EMF |

### 3.3.5 Transmission, storage and distribution of gas

The emission inventories make use of no emission factors in the case of transmission, storage and distribution of gas as the emissions are reported by the gas companies.

### 3.3.6 Flaring

The emission factors for offshore flaring are shown in Table 3.10. The $CO_2$ emission factor is assumed to follow the same time-series as for natural gas combusted in stationary combustion plants. The dioxin emission factor originates from a Danish study by Henriksen et al. (2006) and is, like emission factors for PM, the same as the emission factors used for combustion of natural gas in Danish public power plants. The remaining emission factors are based on the EMEP/CORINAIR Guidebook and are constant for the years 1990-2006. In 2007 the emission factors have been recalculated, which gives a minor divergence according to earlier years. Introducing a conversion factor of 1 055 between $Sm^3$ and $Nm^3$ in the 2007 inventory causes the divergence. Further, the $NO_x$ emission factor has been updated due to the conclusion in a new Danish study of $NO_x$ emissions from offshore flaring carried out by the Danish Environmental Protection Agency (2008). The new $NO_x$ emission factor (31 008 g pr GJ or 0.0015 tonnes $NO_x$ pr tonnes gas) is around one tenth of the old emission factor (300 g pr GJ or 0.015 tonnes $NO_x$ pr tonnes gas) and corresponds well with the emission factors used to estimate $NO_x$ emission in other countries with oil production in the North Sea (Netherlands: approximately 0.0014 tonnes $NO_x$ pr tonnes gas and United Kingdom: approximately 0.0013 tonnes $NO_x$ pr tonnes gas).

Table 3.10 Emission factors for offshore flaring of natural gas 2007.

| Pollutant | Emission factor | Unit |
|---|---|---|
| $SO_2$ | 0.30 | g pr GJ |
| $NO_x$ | 31.01 | g pr GJ |
| NMVOC | 2.40 | g pr GJ |
| $CH_4$ | 4.79 | g pr GJ |
| CO | 23.95 | g pr GJ |
| $CO_2$ | 56.78 | kg pr GJ |
| $N_2O$ | 0.48 | g pr GJ |
| TSP | 0.10 | g pr GJ |
| $PM_{10}$ | 0.10 | g pr GJ |
| $PM_{2.5}$ | 0.10 | g pr GJ |
| Dioxin | 0.025 | ng pr GJ |
| Fluoranthene | 21.00 | mg pr GJ |

## 3.4 Emissions

### 3.4.1 Coal storage

The emission from storage of coal is 1 219 Mg TSP in 2007 (487 Mg $PM_{10}$ and 49 Mg $PM_{2.5}$). The coal consumption and the related emissions vary from year to year mainly due to the extent of electricity import/export and temperature variations (Table 3.11). Note that PM was only included in the inventory from 2000.

Table 3.11 $PM_{10}$ from storage of solid fuels 2000-2007.

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|
| $PM_{10}$, Mg | 385 | 415 | 376 | 571 | 456 | 362 | 521 | 487 |

### 3.4.2 Extraction of oil and gas and loading of ships

From the activity data in Table 3.3, equation 6.4 and equation 6.5 the fugitive emissions of $CH_4$ and NMVOC from extraction are calculated. Corresponding emissions from loading of ships can be estimated by Table 3.3, Table 3.8 and equation 6.6. The emissions are listed in Table 3.12 along with the emissions from storage of oil given in the green accounts from DONG Energy (2008).

Table 3.12 NMVOC emissions for 2007.

| | $CH_4$ tonnes | NMVOC tonnes |
|---|---|---|
| Fugitive emissions from extraction | 1 736 | 582 |
| Oil tanks | 1 780 | 3 917 |
| Offshore loading of ships | 93 | 1 860 |
| Onshore loading of ships | 103 | 2 064 |
| Total | 3 722 | 8 423 |

### 3.4.3 Oil refining

In Table 3.13 the activity data and emissions of $CH_4$ and NMVOC from the two Danish refineries are listed for the years 1990-2007. Further, the emissions of $SO_2$ from oil refining and sulphur recovery in refineries are shown. In years prior to 2004, 1 % of the VOC emission is assumed to be $CH_4$ and 99 % NMVOC. The increase in $CH_4$ emission in

2004 owe to new measurements at one of the two refineries. The emission of $SO_2$ has shown a pronounced decrease since 1990 because of technical improvements at the refineries. Note that $SO_2$ from refining and recovery prior to 1994 was summarized and reported as an area source in the IPCC category 1B2a vi. Note also that $SO_2$ from oil refining from 2001 are included in stationary combustion.

Table 3.13 Oil Refineries. Emissions of NMVOC and $SO_2$ from oil refining and $SO_2$ from sulphur recovery.

| | 1990[1] | 1991[1] | 1992[1] | 1993[1] | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| NMVOC emission, Mg | 3 667 | 3 937 | 4 203 | 4 219 | 5 855 | 4 546 | 5 875 | 4 547 | 4 558 | 4 558 |
| $SO_2$, oil refining, Mg | | | | | 934 | 585 | 167 | 216 | 253 | 234 |
| $SO_2$, sulphur recovery, Mg | 3 335 | 2 713 | 3 147 | 2 526 | 3 332 | 2 437 | 2 447 | 1 766 | 1 188 | 1 125 |

| *Continued* | 2000 | 2001[2] | 2002[2] | 2003[2] | 2004[2] | 2005[2] | 2006[2] | 2007[2] |
|---|---|---|---|---|---|---|---|---|
| NMVOC emission, Mg | 4 983 | 4 338 | 4 302 | 3 708 | 3 732 | 3 550 | 3 848 | 3 773 |
| $SO_2$, oil refining Mg | 178 | | | | | | | |
| $SO_2$, sulphur recovery Mg | 803 | 672 | 332 | 246 | 119 | 255 | 679 | 610 |

[1)]Prior to 1994 $SO_2$ emissions from oil refining and sulphur recovery are reported as area sources in category 1B2a vi.

[2)]From 2001 $SO_2$ emissions from oil refining are included in stationary combustion.

### 3.4.4 Filling stations

Emissions from filling stations are calculated using the emission factors in Table 3.9 and the sold amounts of gasoline given by the Danish Energy statistics. The NMVOC emissions are listed in Table 3.14.

Table 3.14 Emissions of NMVOC from filling stations 1985-2007.

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|
| NMVOC emission, Mg | 4 197 | 4 208 | 4 210 | 4 276 | 4 208 | 4 432 | 3 629 | 2 817 | 2 894 | 2 994 |

| *Continued* | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|
| NMVOC emission, Mg | 3 026 | 2 648 | 2 298 | 1 918 | 1 488 | 1 048 | 1 033 | 1 037 | 1 039 | 1 027 |

| *Continued* | 2005 | 2006 | 2007 |
|---|---|---|---|
| NMVOC emission, Mg | 996 | 977 | 969 |

### 3.4.5 Transmission, storage and distribution of gas

The gas companies give emissions of $CH_4$. The $CH_4$ emissions for transmission are estimated on the basis of registered loss in the transmission grid and the emission from the natural gas consumption in the pressure regulating stations (Oertenblad, 2007). $CH_4$ emissions from gas distribution are estimated by use of emission factors from the Danish EPA and from the gas composition.

The emissions of NMVOC are calculated on the basis of the $CH_4$ emission according to the gas quality measured by Energinet.dk (equation 6.9).

Equation 6.9 $$E_{NMVOC} = E_{CH_4} \times \left( w_{NMVOC} / w_{CH_4} \right)$$

where $w_{NMVOC}$ is the weight-% NMVOC and $w_{CH4}$ is the weight-% $CH_4$ according to the gas quality of the current year.

For the years before 2000 emissions from transmission and storage have not been estimated separately and storage is included in transmission (Table 3.15). The decrease in NMVOC emission from transmission from 2006 to 2007 is caused by the completion of a greater construction work and rerouting of a major pipeline (Table 3.16). As mentioned, the pipelines in Denmark are relatively new and most emissions are due to construction and maintenance. There have been no significant construction work in 2007 and therefore a low emission.

The increased emission from distribution in 2004 owes to venting of the distribution network.

Table 3.15 $CH_4$ emission from transmission, storage and distribution.

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| Transmission Mg* | 98 | 161 | 49 | 102 | 83 | 315 | 104 | 235 | 156 | 191 |
| Storage Mg** | | | | | | | | | | |
| Distribution Mg** | | | | | | 80 | 95 | 23 | 24 | 43 |
| *Continued* | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | | |
| Transmission Mg* | 86 | 157 | 78 | 88 | 85 | 141 | 152 | 7 | | |
| Storage Mg** | 83 | 73 | 67 | 68 | 86 | 54 | 67 | 71 | | |
| Distribution Mg | 49 | 56 | 39 | 39[1,2] | 142[1] | 62[1] | 96[1] | 88[3] | | |

*In 1991-95 $CH_4$ emissions are based on the annual environmental report from DONG Energy for the year 1995. In 1996-99 the $CH_4$ emission refers to the annual environmental reports from DONG Energy for the years 1996-99. In 2000-2006 the $CH_4$ emission refers to DONG Energy/Danish Gas Technology Centre (Karll 2003, Karll 2005, Oertenblad 2006, Oertenblad 2007). In 2007 the $CH_4$ emission refers to the annual environmental reports from Energinet.dk for 2008.

**Danish Gas Technology Centre / DONG/ Danish gas distribution companies (Karll 2003, Karll 2005, Oertenblad 2006, Oertenblad 2007. Emissions from storage are included in transmission 1990-1999.

[1)] Data from Naturgas Fyn not included until 2007 as data has not been available.

[2)] Assumed same emission as in 2002.

[3)] Distribution data are extrapolated from 2006 according to change in transmission data.

Table 3.16 NMVOC emission from transmission, storage and distribution.

| NMVOC emission | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| Transmission, Mg | 30 | 49 | 15 | 31 | 25 | 96 | 32 | 72 | 48 | 58 |
| Storage, Mg*** | | | | | | | | | | |
| Distribution, Mg**, | | | | | | 80 | 95 | 23 | 24 | 43 |
| *Continued* | 2000 | 2001 | 2002 | 2003[1,2] | 2004[1] | 2005[1] | 2006[1] | 2007[3] | | |
| Transmission, Mg | 52 | 48 | 24 | 27 | 26 | 43 | 46 | 2 | | |
| Storage, Mg*** | | 22 | 20 | 21 | 26 | 16 | 20 | 22 | | |
| Distribution, Mg**, | 15 | 17 | 12 | 12[1,2] | 43[1] | 19[1] | 29[1] | 27[3] | | |

*NMVOC emissions are estimated from the $CH_4$ emission according to the gas quality given by Energinet.dk.

**In 1991-95 $CH_4$ emissions are based on the annual environmental report from DONG Energy for the year 1995. In 1996-99 the $CH_4$ emission refers to the annual environmental reports from DONG Energy for the years 1996-99. In 2000-2006 the $CH_4$ emission refers to DONG Energy /Danish Gas Technology Centre (Karll 2003, Karll 2005, Oertenblad 2006, Oertenblad 2007). In 2007 the $CH_4$ emission refers to the annual environmental reports from Energinet.dk for 2008.

***Danish Gas Technology Centre / DONG energy/ Danish gas distribution companies (Karll 2003, Karll 2005, Oertenblad 2006, Oertenblad 2007. Emissions from storage are included in transmission 1990-1999.

[1)] Data from Naturgas Fyn not included until 2007 as data has not been available.

[2)] Assumed same emission as in 2002.

[3)] Distribution data are extrapolated from 2006 according to change in transmission data.

### 3.4.6 Flaring

As shown in Figure 3.7 there was a marked increase in the amount of offshore flaring in 1997 and 1999. The increase in 1997 was due to the new Dan field and the completion of the Harald field. The increase in 1999 was due to the opening of the three new fields Halfdan, Siri and Syd Arne.

The time-series for the emission of $CO_2$ from offshore flaring of natural gas fluctuates due to the fluctuations in the fuel rate and to a minor degree due to the $CO_2$ emission factor. The latter rests on gas quality measurements. Fuel rate and $CO_2$ emission are shown in Figure 3.7.

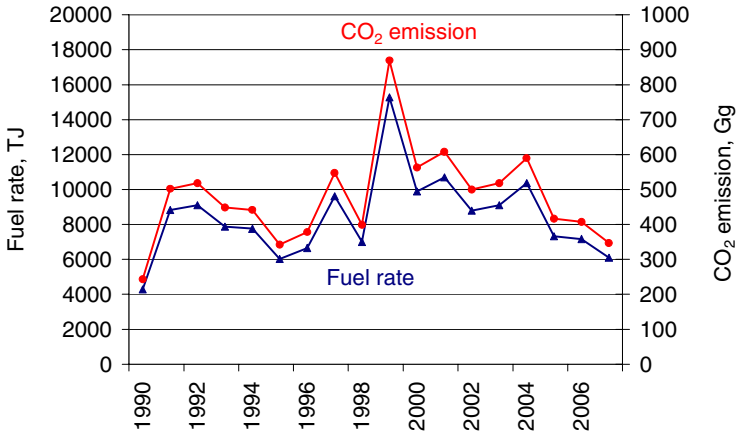


Figure 3.7 Fuel rate and CO2 emission from offshore flaring of gas 1990-2007.

Besides, in the offshore sector flaring also takes place in refineries and gas treatment/storage plants. Flaring in refineries is the most significant emission source for $SO_2$ (Table 3.17 and Table 3.18). In 1990-1993 emissions from petroleum product processing were included in emis-

sions from flaring in refineries (1B2c). From 1994 the data delivery format was changed, which made it possible to split the emissions into contributions from flaring and processing, respectively. Emissions from processing are from 1994 included in 1B2a iv.

The decreasing emissions of $SO_2$ - between 1995 and 1998 - are due to technical improvements of the sulphur recovery system at one of the two Danish refineries (Table 3.17). The increase in $SO_2$ from flaring in refineries in 2005 and 2007 was due to a planned shutdown due to inspection and maintenance of one of the two refineries.

Table 3.17 Emissions from flaring in refineries.

| | 1990* | 1991* | 1992* | 1993* | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes |
| $SO_2$ | 943 | 926 | 935 | 1 190 | 520 | 203 | 218 | 138 | 70 | 50 |
| $NO_x$ | 41 | 41 | 41 | 41 | 235 | 26 | 41 | 27 | 34 | 31 |
| NMVOC | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 22 | 28 | 27 |
| CO | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 3 | 4 | 4 |
| $CO_2$ | 23 | 23 | 23 | 23 | 29 | 23 | 23 | 15 | 19 | 18 |

| *Continued* | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|
| | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes |
| $SO_2$ | 51 | 46 | 68 | 96 | 53 | 296 | 257 | 526 |
| $NO_x$ | 33 | 21 | 39 | 24 | 31 | 26 | 21 | 22 |
| NMVOC | 28 | 18 | 33 | 20 | 26 | 34 | 28 | 28 |
| CO | 5 | 3 | 6 | 3 | 4 | 6 | 5 | 5 |
| $CO_2$ | 19 | 13 | 23 | 14 | 18 | 24 | 19 | 20 |

In 1990-1993 emissions from petroleum product processing were included in flaring in refineries due to the data delivery form. From 1994 emissions from petroleum product processing were given in 1B2a iv.

Table 3.18 Emissions from flaring offshore and in gas treatment/storage plants.

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes |
| $SO_2$ | 1 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 5 |
| $NO_x$ | 131 | 270 | 278 | 242 | 239 | 197 | 208 | 302 | 218 | 480 |
| NMVOC | 13 | 26 | 27 | 23 | 23 | 22 | 22 | 32 | 24 | 49 |
| CO | 105 | 217 | 224 | 195 | 193 | 157 | 170 | 247 | 181 | 391 |
| $CO_2$ | 240 | 495 | 511 | 445 | 439 | 339 | 375 | 548 | 401 | 878 |

| *Continued* | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|
| | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes |
| $SO_2$ | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 |
| $NO_x$ | 313 | 338 | 279 | 292 | 322 | 230 | 225 | 195 |
| NMVOC | 33 | 35 | 31 | 31 | 34 | 25 | 24 | 21 |
| CO | 256 | 276 | 230 | 239 | 263 | 190 | 186 | 160 |
| $CO_2$ | 573 | 619 | 510 | 534 | 588 | 416 | 406 | 347 |

# 4 Projection to 2030 (Oil and gas extraction – Fugitive emissions)

## 4.1 Prognosis

The prognosis for the production of oil and gas 2007-2030 shown in Figure 4.1 presents a path where technological progress and new extraction possibilities are assumed. The prognosis is based on projections made by the Danish Energy Agency (2008a). Note that the Danish Energy Agency regularly updates the prognosis and that the production of natural gas and especially of oil has been reduced significantly according to the latest projection, which has been published after the projection described in this chapter.

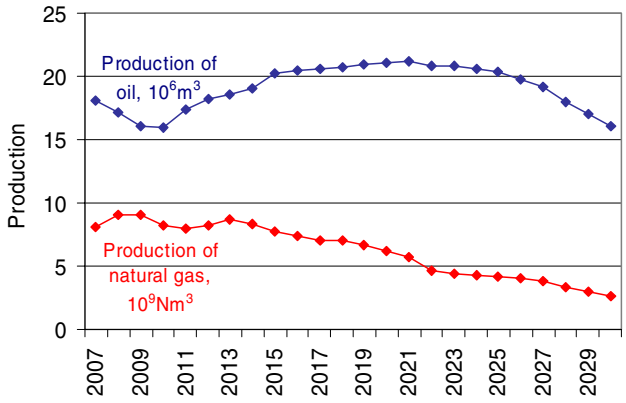


Figure 4.1 Prognosis for the production of oil and gas. Note that in a newer prognosis from the Danish Energy Agency the production of natural gas and oil has been reduced significantly.

## 4.2 Emission factors

In the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007), the emission factors from different countries are provided. The Norwegian emission factors, which are used also in Norway's official emissions inventories (Flugsrud et al., 2000), have been selected for use in the projections (Table 4.1). The emissions from the storage of oil are stated in DONG Energy's environmental accounts for 2007 (DONG Energy, 2008) and the emission factor is calculated based on the amount of oil transported. Emission factors for pipeline gas and network are estimated as a mean for the latest five years in the emission inventory.

Table 4.1 Emission factors used for projection for the years 2008-2009.

| | $CH_4$ | NMVOC | Unit | Ref. |
|---|---|---|---|---|
| Ships offshore | 0.00005 | 0.001 | Fraction of loaded | EMEP/CORINAIR, 2007 |
| Ships onshore | 0.00001 | 0.0002 | Fraction of loaded | EMEP/CORINAIR, 2007 |
| Pipeline, gas | 14.57 | 4.44 | $kg/10^3\ m^3$ | DONG Energy, 2004-2008 & Energinet.dk, 2008 |
| Oil tanks | 112.43 | 245.56 | $kg/10^3\ m^3$ | DONG Energy, 2008 |
| Network | 23.23 | 7.08 | $kg/10^3\ m^3$ | Karll 2005, Oertenblad 2006, Oertenblad 2007 |

According to the environment department of the local authority (Vejle Amt, 2005), stricter regulation of the emissions from oil tanks and onshore loading of ships is going to be introduced. The emission factors for these sources have therefore decreased by 99 % and 46 % for $CH_4$ and by 99 % and 19 % for NMVOC from 2010. The emission factors from 2010 to 2030 are listed in Table 4.2.

Table 4.2 Emission factors used for projection for the years 2010-2030.

| | $CH_4$ | NMVOC | Unit | Source |
|---|---|---|---|---|
| Ships offshore | 0.00005 | 0,001 | Fraction of loaded | EMEP/CORINAIR, 2007 |
| Ships onshore | 0.00000108 | 0.000162 | Fraction of loaded | EMEP/CORINAIR, 2007 and Vejle Amt, 2005 |
| Pipeline, gas | 14.57 | 4.44 | kg/$10^3$ $m^3$ | DONG Energy, 2004-2008 & Energinet.dk, 2008 |
| Oil tanks | 1,13 | 2.46 | kg/$10^3$ $m^3$ | DONG Energy, 2008 |
| Network | 23.23 | 7.08 | kg/$10^3$ $m^3$ | Karll 2005, Oertenblad 2006, Oertenblad 2007 |

## 4.3 Emissions

The emissions of $CH_4$ and NMVOC are calculated on basis of the activity data in Table 4.3 for 2007 and on the projection by the Danish Energy Agency combined with the emission factors in Table 4.1 and Table 4.2 for the years 2008-2030. The $CH_4$ and NMVOC emissions are listed in Table 4.3 and Table 4.4 for 2007 with the projected emissions for 2030. Notice that emissions from flaring are not included as these are calculated in the projection model for stationary combustion.

Table 4.3 Estimated $CH_4$ emissions for 2007 and projected $CH_4$ emissions for 2030.

| $CH_4$ emission | 2007 tonnes | 2030 tonnes |
|---|---|---|
| Extraction | 1 435 | 1 244 |
| Gas terminals | 78 | 78 |
| Pipelines, gas | 99 | 32 |
| Pipelines, oil | 1 732 | 15 |
| Network | 52 | 17 |
| Loading of ships, offshore | 116 | 103 |
| Loading of ships, onshore | 21 | 10 |
| Total | 3 533 | 1 499 |

Table 4.4 Estimated NMVOC emissions for 2007 and projected NMVOC emissions for 2030.

| NMVOC emission | 2007 tonnes | 2030 tonnes |
|---|---|---|
| Extraction | 478 | 415 |
| Gas terminals | 21 | 21 |
| Pipelines, gas | 30 | 10 |
| Pipelines, oil | 3 784 | 34 |
| Network | 16 | 5 |
| Loading of ships, offshore | 2 319 | 2 066 |
| Loading of ships, onshore | 2 054 | 1 483 |
| Total | 8 702 | 4 034 |

The actual and projected $CH_4$ and NMVOC emissions for 2007-2030 are shown in Figure 4.2 and Figure 4.3. The decline in the $CH_4$ and NMVOC emissions in 2010 reflects the expected environmental regulation in emissions from oil tanks and onshore loading of ships, and decreasing extraction of oil and gas. It has been assumed that the number

of platforms falls in line with the decline in extraction. The emission factors are assumed to be the same as those used in the historic inventories except for oil tanks and onshore loading of ships.

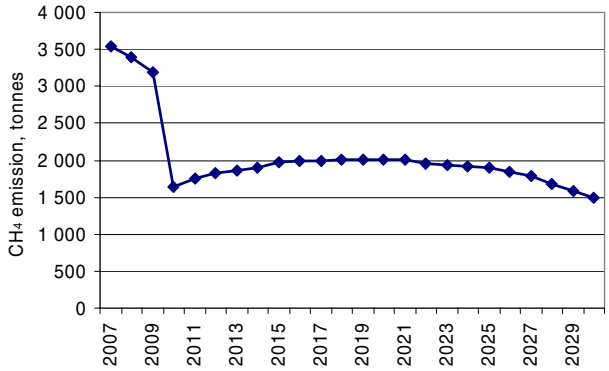


Figure 4.2 $CH_4$ emissions from oil and gas production.

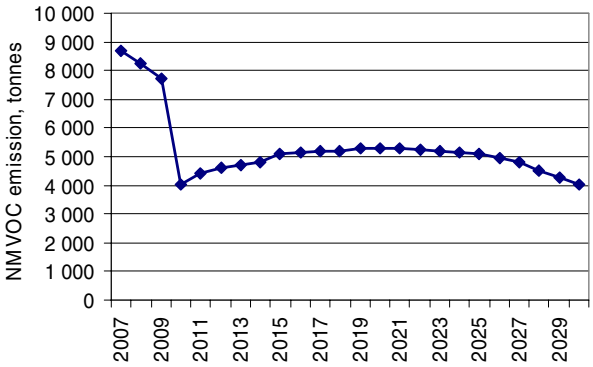


Figure 4.3 NMVOC emissions from oil and gas production.

## 4.4 Model description

The model for the offshore sector is created in MS Excel and the worksheets used in the model are collected in the 'Offshore model'. The names and content of the tables are listed in Table 4.5.

Table 4.5 Tables in the Danish offshore model.

| Name | Content |
|---|---|
| Activity data | Historically data for 2007 (Table 3.3) and estimated activity rates for 2008 to 2030 based on the prognosis for the production of oil and gas (Figure 4.1). |
| Projected production | Projected production of oil and gas for 2008 to 2030. |
| EMF | Emission factors for $CH_4$ and NMVOC for all activities. |
| Emissions | Projected emissions for 2008 to 2030 based on data in tables 'Activity data' and 'Emission factors'. |

The model for gas transmission and distribution is also created in Microsoft Excel and the worksheets are collected in the 'Gas transmission and distribution model'. This model includes activity data, emission factors and emissions.

For both models changing the data in the input data tables automatically updates the projected emissions.

# 5 Uncertainties and time-series consistency

The uncertainties are given in percentages in Table 5.1 and Table 5.2 and will be described here. The uncertainty is given for $CO_2$, $CH_4$ and $N_2O$ for the activity data and the emission factors, separately.

The activity data is based on information from the oil and gas industry except for fugitive emissions from extraction, which is estimated using the standard formula given in the EMEP/CORINAIR Guidebook. As suggested in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, flow rates volumes usually have errors of ±15 % but only ±3 % for flow rate volumes for sales. As the flow rate volumes for other than sales are of greatest importance 15 % uncertainty has been adopted for fugitive emissions in the Danish emission inventory.

The origin of the emission factors vary more than for the activity data. Therefore uncertainty estimations are differed between the components $CO_2$, $CH_4$ and $N_2O$. The $CO_2$ emission factor is the most accurate of the three as it is calculated on the basis of gas quality analysis of natural gas from the North Sea. The calculated $CO_2$ emission factor is used for all fugitive $CO_2$ emissions as the only source is flaring of gas. The IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories suggest that the accuracy for gas composition is usually ±5 %, which is adopted in the Danish emission inventories. The uncertainty estimates for the $CH_4$ and the $N_2O$ emission factors are set to ±50 %. This is in accordance with the upper limit of the uncertainty interval given for a Tier 3 approach in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. For the main part of the fugitive $CH_4$ and $N_2O$ emissions a Tier 3 approach is used. The exception is flaring where standard emission factors for Norway is used. The 2006 EMEP/CORINAIR Guidebook gives an uncertainty estimate of +55 %/-35 % for the sum of vents and fugitive losses, which is in the range of the uncertainty for the Tier 3 approach. The 2006 EMEP/CORINAIR Guidebook suggests an error of 65 % for the standard equation used to estimate fugitive emissions from extraction noting that the error could be much higher when the equation is used for other fields than the ones in USA, which it has been based on. It is expected in the EMEP/CORINAIR Guidebook that it seems to be in reasonable agreement with estimates for Norway and UK.

Estimation of uncertainty is based on the Tier 1 methodology in the IPCC Good Practice Guidance (IPCC, 2000). The results of the uncertainty estimates are shown in Table 5.1.

Table 5.1 Uncertainty calculated for the year 2007, IPCC sector 1B, Fugitive emissions.

| Pollutant | Uncertainty of emission inventory, % | Uncertainty of emission trend, % |
|---|---|---|
| $CO_2$ | 16 | 30 |
| $CH_4$ | 52 | 69 |
| $N_2O$ | 52 | 15 |
| GHG* | 18 | 29 |

*Combined uncertainty estimated in MS Excel according to the IPCC Tier 1 method.

Uncertainty of activity rates for oil and gas activities is 15 %, referring to the GPG. The uncertainty of emission factors for $CO_2$ is the uncertainty of emission factors for flaring. This emission factor uncertainty is 5 % (GPG). Uncertainty with regard to $CH_4$ and $N_2O$ emission factors is assumed to be 50 % in both cases (Table 5.2).

Table 5.2 Uncertainty of activity rates and emission factors.

| | Uncertainty Activity Rate, % | Uncertainty Emission Factor, % |
|---|---|---|
| $CO_2$ | 15 | 5 |
| $CH_4$ | 15 | 50 |
| $N_2O$ | 15 | 50 |

# 6 Quality Assurance and Quality Control (QA/QC)

Table 6.1 lists the external data deliveries used for the inventory of fugitive emissions. Further the table holds information on the contacts at the data delivery companies.

Table 6.1 List of external data sources.

| Dataset | Description | Activity data, emission factors or emissions | Reference | Contact(s) | Data agreement/ Comment |
|---|---|---|---|---|---|
| Data for offshore extraction | Gas and oil production. Dataset for production of oil, gas and number of platforms. CRF 1B2a | Activity data | The Danish Energy Agency (DEA) | Jan H. Andersen | No formal data agreement. |
| Gas distribution | Natural gas from the distribution company, sales and losses (meter differences) | Activity data | DONG Energy, HNG and MN, Naturgas Fyn | Finn Adser, Ole B. Hansen & Sofie Faaborg-Andersen, Ron Cronin | No formal data agreement. |
| Gas transmission | Natural gas from the transmission company, sales and losses (meter differences) | Activity data | Energinet.dk | Christian Friberg B. Nielsen | - |
| Environmental report from DONG Energy | Gas and oil production. The amount of oil loaded onshore and emissions from raw oil tanks. CRF 1B2a | Activity data and emission data | DONG Energy | Mike Robson | Not necessary due to obligation by law |
| Air emissions from refinery (Statoil and Shell) | Fuel consumption and emission data. CRF 1B2a. | Activity data and emission data | Statoil, Shell | Claus Stefan Kock, Lis Rønnow Rasmussen | No formal data agreement. |
| Environmental indicators of the gas industry | Data for natural gas transmission/distribution and storage. CRF 1B2b. | Activity data and emission data | DONG Energy, HNG and MN, Naturgas Fyn | Finn Adser, Ole B. Hansen, Sofie Faaborg-Andersen | No formal data agreement. |
| Filling stations | Data on gasoline sales | Activity data | The Danish Energy Agency (DEA) | - | |
| $CO_2$ quota reports | Reports according to the $CO_2$ emission trading scheme | Activity data | | - | Not necessary due to obligation by law |
| Emissions from storage and treatment of gas | Green accounts from plants defined as large point sources (Lille Torup, Stenlille, Nybro) | Activity data | Various plants. | - | Not necessary due to obligation by law |
| Off shore flaring | - | Activity data | The Danish Energy Agency | - | Data agreement |
| Emission factors | Emission factors origin from a large number of sources | Emission factors | See chapter regarding emission factors | - | - |

## 6.1 The Danish QA/QC plan

The elaboration of a formal QA/QC plan started in 2004 and the first version is available (Sørensen et al., 2005). The plan describes the concepts of quality work and definitions of sufficient quality, critical control points and a list of Points of Measuring, PM (Figure 6.1).

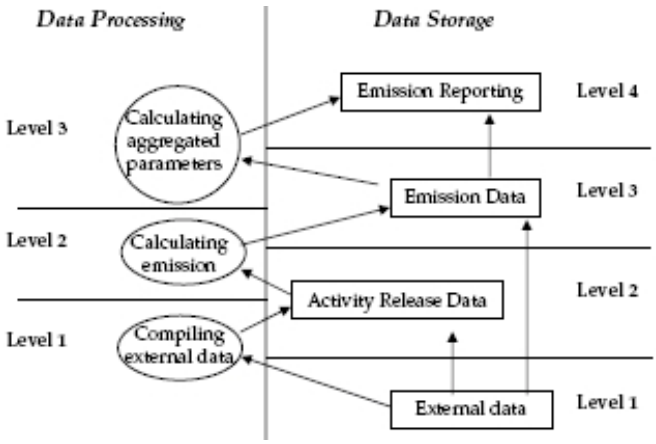


Figure 6.1 The general data structure for the Danish emission inventory (Sørensen et al., 2005).

**Data storage level 1**

Data storage level 1 refers to the data collected by NERI before any processing or preparing.

The uncertainty of the external data is not quantified but it is assumed that the level of uncertainty is relatively small except for the emissions from the refineries. All external data are stored in the inventory file system or in hard copy and are available for all members of the inventory staff. It is aimed to make formal agreements on data delivery. Part of the data on Danish fugitive emissions is made available due to legal obligations, here among the energy statistics, $CO_2$ quota reports and the green accounts. There are yet no formal agreements on data delivery with the refineries and the gas distribution companies. The latter because data is not longer reported to the Technical Association of the European Natural Gas Industry, Marcogaz, by the Danish Gas Technology Centre.

**Data Processing Level 1**

Data processing level 1 refers to the processing of the collected data before it can be incorporated in the emission calculation.

The methodological approach is consistent with the international guidelines as described in the previous chapters in this report. Time-series for activity data on SNAP level as well as emission factors are incorporated in the procedure to identify errors in the incoming data and in the calculation procedure. During the calculation process, numerous controls are in place to ensure correctness, e.g. sum checks of the various stages in the calculation procedure. There are direct links between the external datasets, the calculation process and the input data used on Data Storage level 2.

**Data storage level 2**

Data storage level 2 refers to storage of data that have been processed.

To ensure a correct connection between data on level 1 to data on level 2, different controls are in place, e.g. control of sums and random tests. The same procedure is applied every year in order to minimise the risk of data import errors.

#### Data Processing level 2

Data Processing level 2 refers to calculation of emissions. The calculations are incorporated in the Off-shore Model and the Gas distribution and transmission model, which are both stored in MS Excel in the Danish inventory file system.

#### Data Storage level 3

Data Storage level 3 refers to the emission data either given directly in or calculated from the data in Data Storage level 1. The emissions are stored in MS Excel on both source level and aggregated on SNAP level for export to the overall inventory storage system.

#### Other QC procedures

A list of QA/QC tasks are performed directly in relation to the fugitive emission part of the Danish emission inventories. The following procedures are carried out to ensure the data quality:

- Checking of time-series in the IPCC and SNAP source categories. Considerable changes are controlled and explained.
- Comparison with the inventory of the previous year. Any major changes are verified.
- Total emission, when aggregated to IPCC and LRTAP reporting tables, is compared with totals based on SNAP source categories (control of data transfer).
- A manual log table in the emission databases is applied to collect information about recalculations.
- Emission from large point sources (refineries, gas treatment and storage plants) are compared with the emission reported the previous year.
- Some automated checks have been prepared for the emission databases:
  - Check of units for fuel rate, emission factor and plant-specific emissions.
  - Check of emission factors for large point sources. Emission factors for pollutants that are not plant-specific should be the same as those defined for area sources.
  - Additional checks on database consistency.
- Most emission factor references are now incorporated in the emission database, itself.
- Most data sources are implemented in the fugitive emission model.
- Annual environmental reports are kept for subsequent control of plant-specific emission data.

The QC work will continue in future years.

# 7 Improvements in the future

The following source specific improvements are suggested in the future:

- **Emissions from storage of fuels in tank facilities:** The most recent edition of the Danish emission inventory holds emissions from extraction of fuels, combustion of fuels and from filling stations. To make the inventory complete emissions from storage of fuels in tank facilities should be included in the future. Work is ongoing to locate greater tank facilities in Denmark and collect the available data. In cases where no emission estimates or measurements are available a set of emission factors has to be set up.
- **Emissions from town gas:** Work is ongoing to add an improvement to the Danish inventories by including emissions from town gas distribution. In earlier years town gas was used in Denmark to a great extend, but most plants were closed during the seventies owing to the oil crisis. Since 1985 only four plants have had town gas production. Two gas plants were shut down in January 2004 and November 2005, respectively, leaving only two cities with a town gas supply today. Collection of data on town gas, including production, distribution, networks and gas loss is in process.
- **Emissions from offshore extraction of oil and gas:** The fugitive emissions from extraction of oil and gas are based on a standard formula. If possible a better estimate should be implemented.

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# EMISSION INVENTORY FOR FUGITIVE EMISSIONS IN DENMARK

This report presents the methodology and data used in the Danish inventory of fugitive emis-sions from fuels for the years until 2007. The inventory of fugitive emissions includes CO2, CH4, N2O, NOx, CO, NMVOC, SO2, dioxin, PAH and particulate matter. In 2007 the total Danish emis-sion of greenhouse gasses was 66 641 Gg CO2-eqvivalents. Fugitive emissions from fuels ac-count for 496 Gg CO2-eqvivalents or approximately 1 %. The major part of the fugitive emis-sions are emitted as CO2 (74 %) due to flaring of oil and gas. The major source of fugitive CH4 emission is extraction of oil and gas in the North Sea, refining of oil and loading of oil onto ships both offshore and onshore. The fugitive emissions of NMVOC originate for the major part from extraction, loading of ships, transmission and distribution of oil and to a much lesser degree from natural gas and fugitive emissions from gas stations. The total Danish emission of NMVOC in 2007 is 103 Gg. Fugitive emissions account for 13 Gg, which corresponds to 13 %. Time se-ries for emissions are presented for the years 1990-2007, except for particulate matter where the time series covers 2000-2007. Further, projections are described for the years 2008-2030.

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