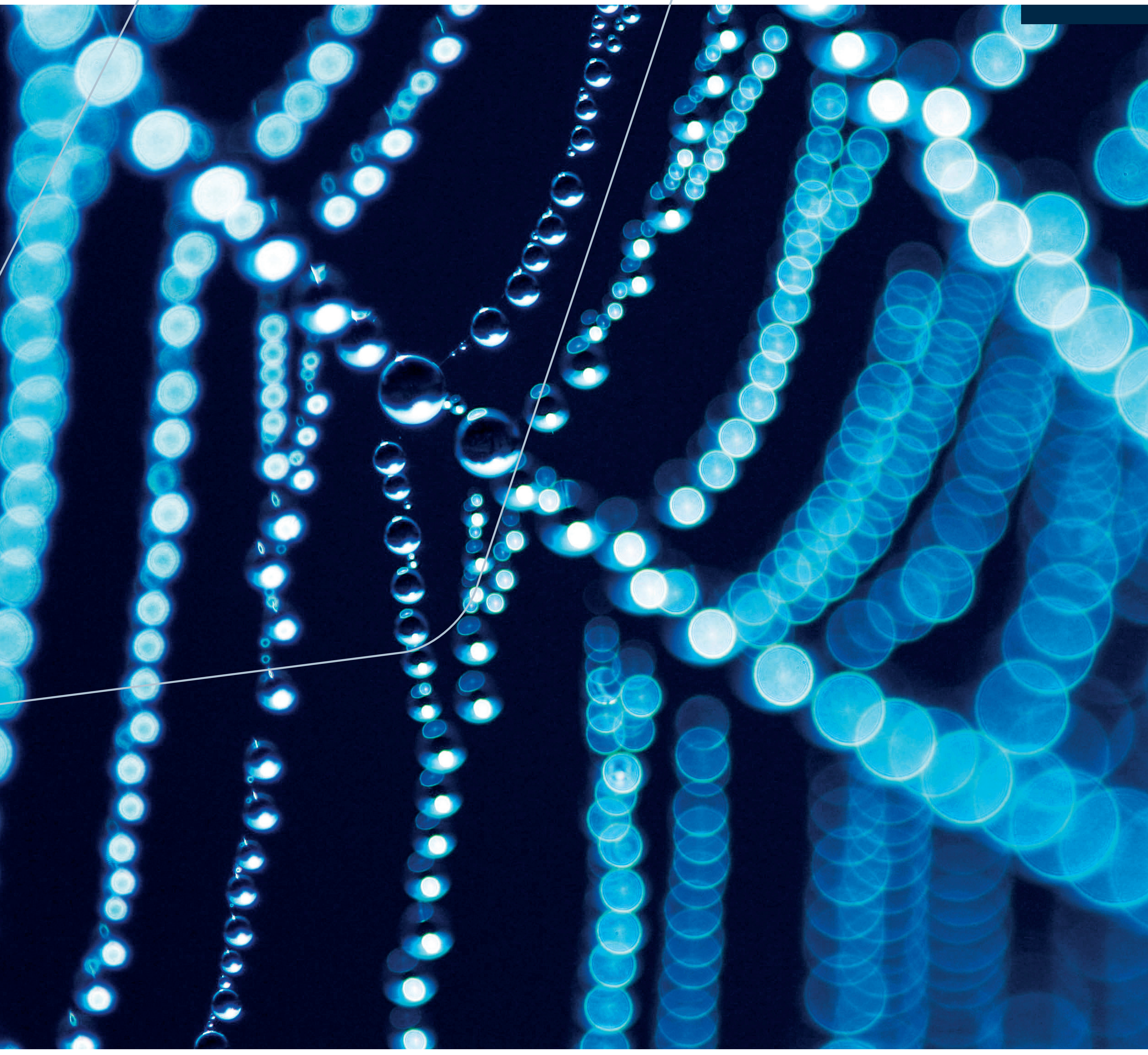
Environmental Report 2009



Environmental Report 2009
for Energinet.dk

Environmental Report 2009

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1. Background to and summary of Environmental Report 2009

Environmental Report 2009 gives an account of the environmental impacts of Danish electricity and CHP generation in 2008. The data on which the Environmental Report is based comprise power generator statements from Danish power generators producing more than 5 $MW_{electricity}$ and 20 $MW_{thermal}$. These statements cover 92% of total Danish thermal electricity generation. The Environmental Report also outlines the most significant environmental impacts from the operation of the transmission systems for electricity and natural gas in 2008. Detailed descriptions of the environmental impacts can be found in the background report to Environmental Report 2009 (in Danish only). Information about the impacts on the landscape of the electricity and natural gas transmission systems, including environmental impacts during the establishment of overhead lines or the undergrounding of pipelines and cables, is also available at www.energinet.dk.

Since 1997, the transmission system operator (TSO) has published annual environmental reports, plans and reviews with the purpose of creating an overview of the environmental considerations within the electricity sector. The environmental report also contributes to the assessment of objectives implemented in Danish environmental and energy strategies. As the system operator of electricity and natural gas transmission in Denmark, Energinet.dk is obliged by the Danish Electricity Supply Act to submit an annual environmental report to the Danish Minister for Climate and Energy.

Environmental Report 2009 considers the following four main topics:

- A status of the environmental impacts from the Danish power system in 2008. This includes a presentation of the most significant figures for the electricity and CHP generation, electricity exchanges with neighbouring countries and emissions of the substances subject to emission allowances, ie carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x).
- The Environmental Impact Statement for electricity, which states the environmental impact of consuming one kWh of electricity. The statement comprises a total of eight emissions to air, seven residual products and eight fuel types.
- Historical analysis of environmental conditions in the electricity sector for the period 1990-2008 and forecasts for future environmental impacts of the electricity sector up to 2020. It describes developments in electricity consumption, electricity generation, fuel consumption and CO_2, SO_2 and NO_x emissions.
- The environmental impacts of transmitting electricity and natural gas in the electricity and natural gas transmission systems, and of storing natural gas in Energinet.dk's natural gas storage facility in Lille Torup.

The power systems in Eastern and Western Denmark are not connected. Consequently, several sections of Environmental Report 2009 will be divided into Eastern and Western Denmark when there are relevant differences between the two areas.

1.1 Status 2008

In 2008, Danish electricity and CHP generation were characterised by greatly fluctuating electricity prices. Throughout spring and summer, prices on the commodity market rose, which led to increases in the price of electricity. In autumn, commodity prices fell as the financial crisis gradually impacted, which resulted in a fall in electricity prices towards the end of the year. Overall, prices in the electricity market were 75% higher in 2008 than in 2007.

After the transition to the Kyoto period 2008-2012, the prices of CO_2 emission allowances rose, which has also been a contributing factor to the increase in the overall price of electricity.

Overview - Status 2008
Significant environmental and energy related key figures for the status year 2008 are shown below.

- Electricity generation from power stations fell from 23.1 TWh in 2007 to 20.8 TWh in 2008.
- Generation from Danish wind turbines dropped from 7.2 TWh in 2007 to 7.0 TWh in 2008. This was due to less favourable wind conditions than those of 2007. The energy content of the wind was average in 2008, whereas in 2007, it was 8% above average. In 2008, the total RE share of Danish electricity generation was 29.6%. Wind power's share of electricity generation was 20.1%
- In 2008, generation from local CHP plants remained mostly unchanged in relation to 2007. Generation in 2008 was 6.9 TWh compared with 6.8 TWh in 2007
- Similar to 2007, Eastern Denmark experienced net imports in 2008. The generation deficit increased steeply from 820 GWh in 2007 to 2.481 GWh in 2008.
- In 2008, Western Denmark experienced net exports and a net generation surplus of 1,028 GWh. In 2007, Western Denmark also experienced net exports and a net generation surplus of 1,775 GWh.
- In 2008, emissions of CO_2, SO_2 and NO_x fell by 9%, 26% and 28% respectively.

These falls are mainly attributable to a reduction in emissions from the central power stations.

- In 2008, total CO_2 emissions from electricity and CHP generators participating in the emissions trading scheme were 19.5 million tonnes, corresponding to a decrease of approx. 10% compared with 2007.
- With realised emissions of 4,945 tonnes, SO_2 emissions from facilities participating in the emissions trading scheme were significantly lower than the 2008 allowance of 22,000 tonnes.
- In 2008, NO_X emissions adjusted for exchange totalled 16,762 tonnes. The 2008 allowance for NO_X emissions was 22,000 tonnes, thereby maintaining a comfortable margin.
- The executive order on large combustion plants imposed stricter requirements for SO_2 and NO_X emissions from January 2008. The installation of deNO_X units at Fyn Power Station Unit 3 and Studstrup Power Station are among some of the measures taken to observe this requirement.
- In practice, allowance schemes for SO_2 and NO_X no longer influence the regulation of the emissions of these substances, because these emissions are already far below the preset requirements.

1.2 Environmental Impact Statement 2008

Environmental Impact Statement and Electricity Label

Energinet.dk has prepared two types of impact statements for Environmental Report 2009: the Environmental Impact Statement and the Electricity Label. Both have been prepared for Eastern and Western Denmark. The Electricity Label is available in two types: a general label for average electricity and an individual label for electricity with special environmental properties.

Overview - Environmental Impact Statement 2008

Selected events from 2008 within the field of Environmental Impact Statements and Electricity Labels are described below:

- The Environmental Impact Statement and the Electricity Labels for 2008 were published on Energinet.dk's website on 27 February and 23 March 2009 respectively.
- In 2008, the fuel mix for 1 kWh of average electricity in Eastern Denmark consisted of 35% coal, 19% natural gas, 13% waste, biomass and biogas; 20% wind, hydro and solar power; 5% oil and 8% nuclear power.
- Eastern Denmark experienced net imports in 2008. Therefore, imports of hydropower and nuclear power from Sweden have been included in the Environmental Impact Statement for Eastern Denmark. In 2008, imports from Sweden constituted 17% of Eastern Denmark's consumption.
- In 2007, the fuel mix for 1 kWh of average electricity in Western Denmark consisted of 46% coal, 20% natural gas, 9% waste, biomass and biogas; 24% wind, hydro and solar power and 1% oil.
- The Environmental Impact Statement for 2008 shows an overall drop in emissions to the air for all substances stated for Eastern Denmark, primarily as a result of the increased imports of Swedish electricity.
- In the Environmental Impact Statement for 2008, emissions for Western Denmark are virtually unchanged compared with 2007. Notable exceptions to this are NO_X and SO_2, which have fallen due to reduced emissions from the large power stations.
- In Eastern Denmark, CO_2 emissions per consumed kWh of electricity dropped substantially to 429 g/kWh in 2008 from 543 g/kWh in 2007. This is primarily due to rising imports of Swedish electricity.
- CO_2 emissions in Western Denmark were 449 g/kWh in 2008, compared with 445 g/kWh in 2007.

1.3 History and forecasts 1990-2020

Energinet.dk prepares statutory forecasts for the electricity generation sector. Normally, the forecast period covers a ten-year span. However, in this year's report, we have decided to include the years up to and including 2020 to enable the assessment of developments in relation to the EU's 2020 targets. The forecasts are based on simulations that include a series of analysis assumptions. It is assumed, for example, that offshore wind farms are expanded by 1,800 MW during the forecast period and that the Great Belt Power Link is commissioned in 2010. The forecasts are prepared assuming normal climate and precipitation conditions. Kyoto periods I and II are covered by the forecast period.

Overview – History 1990-2008 and forecasts 2009-2020

The most important environmental impacts of electricity generation from a historical perspective as well as an estimate of the generation and impacts up to 2020 are summarised below.

- In 2008, electricity consumption in Denmark fell by 1.9% in relation to 2007. According to the forecast up to 2020, electricity consumption is expected to increase by approx. 19% in the period. Included in this increase is consumption for heat pumps and electric vehicles, for instance.
- In the forecast for Denmark for the period up to 2020, the central power stations' share of electricity generation is expected to fall from 60% in 2008 to 49% in 2020, while wind turbines increase their share from 19% to 36%.
- Regarding fuels, the relative share constituting waste and biomass is expected to increase. Consumption of coal is expected to decrease during the forecast period from 2009-2020.
- Wind power is expected to expand significantly during the forecast period. Installed wind turbine capacity is expected to increase by approx. 75% in 2020 in relation to 2008. This increase in capacity will stem primarily from offshore wind farms.
- Generation from wind turbines is expected to increase from 7 TWh in 2008 to 15 TWh in 2020. This increase will stem primarily from offshore wind turbines, which are expected to constitute approx. 48% of wind power generation in 2020, compared with approx. 28% in 2008.
- SO_2 emissions are significantly below the emission allowance for the entire forecast period. Expectations for 2009-2020 indicate a stable yet low emission of SO_2 for the entire period.
- NO_x emissions adjusted for exchange from facilities exceeding 25 $MW_{electricity}$ are expected to be approx. 6,000 tonnes below the allowance in the forecast period 2009-2020. The smaller facilities are expected to account for 42% of total NO_x emissions at the end of the forecast period.

1.4 Electricity transmission grid

The most significant environmental impact of the transmission of electricity is transmission losses. SF_6 gas is employed as an insulation medium in connection with the operation and maintenance of the transmission system, for example in high-voltage components and indoor substation units. SF_6 gas is a very aggressive greenhouse gas, and emissions of SF_6 therefore constitute an environmental impact in connection with electricity transmission.

Overview – Electricity transmission grid

- In 2008, transmission losses stood at 2.3% and 2.4% in Eastern and Western Denmark respectively. This yielded total transmission losses of 845 GWh. The environmental impact from transmission losses in 2008 corresponds to a greenhouse gas emission of 382,946 tonnes of CO_2 equivalents.
- In 2008, total emissions of SF_6 gas were 355 kg, corresponding to 9,502 tonnes of CO_2 equivalents.

1.5 Natural gas transmission grid

Natural gas transmission in Energinet.dk's natural gas transmission grid has three significant environmental impacts: One involves direct emissions of natural gas, for instance during gas pipeline repairs. Another impact occurs when natural gas is used as a fuel at M/R stations for heating the natural gas. The burnt natural gas leads to emissions of mainly CO_2. The third environmental impact occurs when odorants are added to the gas. SO_2 is released when the odorant is burnt at the end-user's premises.

Lille Torup natural gas storage facility is owned and operated by Energinet.dk Gaslager A/S, a subsidiary of Energinet.dk. The environmental impacts of natural gas storage operations are stated in the statutory annual green accounts. The most significant information can be found in the section pertaining to natural gas transmission.

Overview – Natural gas transmission grid

- In 2008, a total of 7.6 billion Nm^3 of natural gas was transmitted. This is an increase compared with 2007, when the transmission of natural gas reached 6.4 billion Nm^3. However, consumption in Denmark remained mostly unchanged; the increased volume of natural gas was exported primarily to Germany.
- In 2008, 24,204 Nm^3 of natural gas was emitted in connection with the transmission of natural gas, which corresponds to 344 tonnes of CO_2 equivalents.
- In 2008, 37,286 MWh were used for heating natural gas in M/R stations. This resulted in the emission of 7,705 tonnes of CO_2 equivalents.
- In 2008, consumption of odorants reached 55,565 litres. This constitutes an increase of some 13,000 litres compared with 2007.
- At Lille Torup natural gas storage facility, electricity consumption was 10,834 MWh in 2008. Electricity is used for pumping natural gas into the storage facility and therefore depends on the volume of natural gas injected into the storage facility.
- When natural gas is withdrawn from the facility, it is heated before being led into the transmission grid. In 2008, boiler gas consumption totalled 835,112 Nm^3. This includes condensate used for heating.

2. Status for 2008

This chapter provides a status of the environmental impacts from Danish electricity and CHP generation for 2008. The status serves several purposes:

- It gives an account of significant environmental aspects from the generation of electricity. According to the Danish Electricity Supply Act, Energinet.dk is obliged to prepare an annual statement on the subject.
- It gives an account of the emission of CO_2 and the allocation of emission allowances in pursuance of the national allocation plan, see the Danish CO_2 Emission Allowances Act.
- It describes the status of SO_2 and NO_x emissions and contains the same information that is submitted separately to the Danish Energy Agency in accordance with the executive order on SO_2 and NO_x emission allowances.

To meet these objectives, Energinet.dk collects large amounts of data from all electricity-generating facilities in Denmark.

Energinet.dk constantly records data from all the electricity-generating units that supply the public grid. In addition, Energinet.dk collects specific data on emissions and fuel consumption from Danish electricity and CHP generators. For Environmental Report 2009, data have been collected from all power generators with a capacity of more than 5 $MW_{electricity}$ and/or more than 20 $MW_{thermal}$.

These statements cover 92% of total Danish thermal electricity generation. For facilities that do not fulfil the aforementioned criteria, Energinet.dk estimates the environmental impact based on the recorded electricity generation and knowledge of the fuel types and efficiency at the facilities, etc. The background report to Environmental Report 2009 describes the data basis and calculation methods in detail.

The volume of Danish electricity generation varies considerably from one year to the next due to variations in the exchange of electricity with neighbouring countries.

The extent of electricity trading with other countries is mainly determined by international competition conditions and limitations on the capacity of international interconnections.

The Danish electricity market is an integral part of the Nordic electricity market and is therefore influenced greatly by the development of prices on the Nordic power exchange Nord Pool. Trading possibilities with the Nordic countries greatly depend on the volume of hydropower available in the Nordic region. Hydropower generation in the Nordic region is more substantial and cheaper during years of high precipitation. During years of high precipitation, we usually experience low Danish electricity generation since a great deal of cheap hydropower is imported from Norway and Sweden. Conversely, Danish electricity generation is usually higher during years of low precipitation. Large central power stations in particular and, in recent years, natural gas-fired power plants operating on market terms adjust their generation according to the development of prices on the electricity market.

The environmental impact of electricity and CHP generation in Denmark closely follows the development of generation, that is to say, in a year of high productivity, the corresponding environmental impact will be typically greater. However, the commissioning of new generation units and the scrapping of older facilities along with the introduction of environmental improvements at existing power stations in the form of improved efficiencies, flue gas treatment and fuel changes have the potential to significantly influence the overall environmental impacts of the electricity sector.

2.1 Conditions for electricity and CHP generation in 2008

Fluctuations in international market conditions had a significant bearing on the electricity market in 2008. Prices in the commodity markets, especially oil and coal prices, rose to record levels throughout the spring and summer. As the financial crisis in the autumn forced commodity prices down, electricity prices also fell. On average, Danish wholesale electricity prices were 75% higher in 2008 than in the previous year.

As of 2008, the second phase of the EU's Emission Allowance Trading Scheme commenced. The transition to the Kyoto period 2008-2012 has resulted in a significant tightening of the allocation of emission allowances in the national allocation plans (NAPs) and therefore a considerable rise in the emission allowance price. The CO_2 emission allowance price closely followed the development in the commodity markets and thus rose throughout the first half of 2008. The emission allowance price reached its highest level of DKK 200 per tonne in June. In autumn, the emission allowance price followed the general downturn in economic market conditions and ended at approx. DKK 120 per tonne in December.

Despite generally higher prices on the electricity market in 2008 than in 2007, imports from the Nordic countries to both Eastern and Western Denmark increased, which was due to a positive water balance in the Nordic water reservoirs for most of the year. Most notably, there was a substantial increase in imports from Sweden to Eastern Denmark in 2008.

The executive order on large combustion plants concerns requirements for emissions of SO_2, NO_X and particles from units exceeding 50 $MW_{thermal}$. Units established before 1 July 1987 had a deadline until 1 January 2008 to meet the emission requirements of the order. For other units exceeding 50 MW, the emission thresholds were established in 2003. However, stricter requirements for NO_X emissions have been imposed on existing units (environmental approval 8 October 2003) in 2008. Several plant owners have therefore invested in new environmental equipment or taken other measures to observe the stricter requirements in the executive order. Most recently, Studstrup Power Station and Fyn Power Station Unit 7 have established $deNO_X$ units. Conversely, Stigsnæs Power Station Unit 1 and Asnæs Power Station Unit 4 have been decommissioned from normal operation because they are unable to observe the strict emission limit values.

On the system side, 2008 was dominated by the following incidents affecting transmission capacity to neighbouring countries: The interconnection between Norway and Western Denmark (Skagerrak 3) was recommissioned at the end of June after an outage time of almost one year. The Kontek Link between Eastern Denmark and Germany was taken out of operation at the end of February due to an oil leak and was recommissioned two months later.

Table 1 Key figures for electricity generation in Denmark in 2008..

Key figures for 2008	Eastern Denmark	Western Denmark	Denmark Total
Wind share of net generation in area	14.9%	22.9%	20.1%
Wind share of consumption in area	12.6%	24.6%	19.8%
RE share of net generation in area	27.8%	30.6%	29.6%
2008 electricity accounts for the grid	**GWh**	**GWh**	**GWh**
Generation ex plant (gross including own consumption)	12,796	23,927	36,723
Generation ex plant (net including own consumption)	12,001	22,648	34,649
Imports, gross	4,949	7,769	12,718
Exports, gross	2,467	8,797	11,264
Transmission losses	359	518	877
Sale to distribution grid	14,124	21,102	35,226
Specification of electricity generation	**GWh**	**GWh**	**GWh**
Electricity from wind turbines	1,786	5,192	6,977
Electricity from hydropower and photovoltaics	0.10	27	27
Electricity from thermal generation on RE fuels	1,549	1,708	3,257
Electricity from thermal generation on non-RE fuels	8,666	15,721	24,387

Note: RE fuels are biomass fuels such as wood chips, wood pellets, wood and biomass waste, straw, landfill gas, biogas and the biodegradable fraction of waste. Non-RE fuels comprise fossil fuels such as coal, oil, natural gas, refinery gas and the non-biodegradable fraction of waste.

2.2 Key figures for electricity and CHP generation in 2008

Table 1 shows the key figures for electricity generation in Eastern and Western Denmark in 2008. The key figures specify generation based on various fuel types, volume of generation, imports, exports, transmission losses and consumption (sale to distribution network).

In 2008, total Danish electricity generation was 34,649 GWh, which is approximately 6% less than in 2007. Denmark went from having a small generation surplus in 2007 to becoming a net importer of electricity in 2008. However, both 2008 and 2007 can be described as years of high precipitation with less electricity generation in Denmark. Compared to 2006, which was a dry year with high electricity generation, the electricity generation level in Denmark was 19% lower in 2008.

Electricity generation from the power stations fell from 23,057 GWh in 2007 to 20,804 GWh in 2008. In the period 2005-2007, there was a gradual reduction in annual generation from local CHP plants as an even greater number of local CHP

Table 2 Fuel consumption of thermal electricity generation units in 2008.

Fuel consumption in 2008, PJ	Eastern Denmark	Western Denmark	Denmark Total
Coal	55	108	163
Natural gas	29	43	72
Oil	8	4	12
Waste	15	20	35
Biofuels	12	13	25
Total	119	189	307

1 PJ (Petajoule) = 1 million GJ (Gigajoule) = 278 GWh.

plants changed to selling their electricity generation on market terms. Most notable in the period is a reduction in electricity generation from natural gas-fired power stations on market terms. Contrary to this trend, local electricity generation remained virtually unchanged, from 6,797 GWh in 2007 to 6,867 GWh in 2008. However, local electricity generation in 2008 was still well below the levels in the years 2000-2004, which were approx. 9,000 GWh.

In 2008, national wind power generation was 6,977 GWh, a slight fall compared to 2007, when wind power generated 7,171 GWh. This fall was due to less favourable wind conditions in 2008 than in 2007. Compared to 2007, when the wind energy content was 108% of the norm, 2008 can be described as an average wind year. Overall, wind turbine capacity rose by approx. 40 MW in 2008. In 2008, the total RE share of the Danish power generation was approx. 29.6%, with wind power accounting for 20.1% of the total electricity generation.

In 2008, 54,566 TJ of heat was generated at central power stations and 56,054 TJ of heat at local CHP plants. Total heat generation at the CHP plants was 110,620 TJ (30,728 GWh) nationally. The statement comprises both heat for district heating and industrial use.

2.3 Distribution of electricity generation and fuel consumption in 2008

The power stations' share of the total electricity generation fell from approx. 62% in 2007 to 60% in 2008. The remaining Danish electricity generation in 2008 was virtually divided evenly between local CHP plants and non-thermal renewable electricity (wind, water, sun).

The fuel consumption of power stations and local CHP plants can be divided into fossil fuels (coal, oil and natural gas) and waste and biofuels (biomass and biogas). Fuel consumption of the thermal electricity generation units in 2008 can be seen in **Table 2.**

The fall in Danish electricity generation from 2007 to 2008 occurred principally at the large coal-fired power stations. Consequently, consumption of both coal and oil fell by nearly 12% in 2008.

Total electricity efficiency of thermal generation in Denmark was 32.4% in 2008, while the total efficiency (electricity and heat) of thermal generation in Denmark was 68.3%. The figures represent an average for the total fuel efficiency.

2.4 Electricity generation from renewable energy sources and fuels

In 2008, the RE share of net electricity generation in Denmark totalled 29.6% (see **Table 1**). Electricity generation from renewable energy sources is dominated by wind power, yet RE electricity also comprises

Figure 1 Composition of renewable electricity generated in Western Denmark.

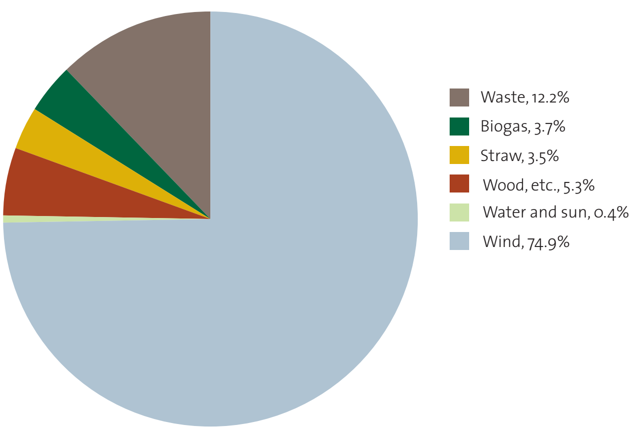
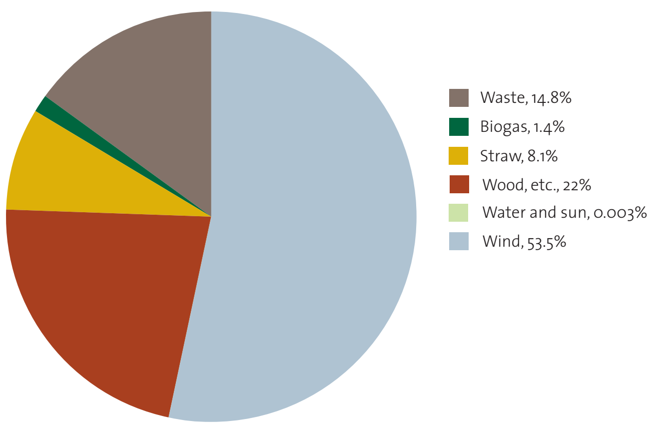


Figure 2 Composition of renewable electricity generated in Eastern Denmark



electricity generation from the biodegradable fraction of waste, biogas, straw, wood (wood pellets, wood chips, wood and biomass waste), hydropower and photovoltaic cells. In 2008, total RE generation was 3,335 GWh in Eastern Denmark and 6,927 GWh in Western Denmark. The composition of renewable electricity in 2008 is shown in **Figures 1** and **2.**

2.5 International exchange in 2008

The Danish transmission grid is connected to electricity systems abroad. Eastern Denmark exchanges electricity with neighbouring countries Sweden and Germany. Western Denmark interconnects with Norway, Sweden and Germany.

Eastern Denmark
As in 2007, Eastern Denmark experienced net electricity imports in 2008. Eastern Denmark thus had a net generation deficit of 2,481 GWh in 2008.

Figure 3 illustrates the monthly net exchange with neighbouring countries in 2008. Positive values indicate imports to Eastern Denmark, while negative values show exports from Eastern Denmark. The physical exchange is stated as hourly mean values based on hourly metering. On an annual basis, Eastern Denmark experienced net electricity imports, but as seen in **Figure 3**, there were primarily net imports in the period March to September. There were net imports from Sweden in all months of the year except November and net exports to Germany for the entire year with the exception of August.

For the whole of March and much of April, there was no exchange with Germany because of an outage on the Kontek Link between Eastern Denmark and Germany.

Western Denmark
Overall, Western Denmark had net exports of electricity to the neighbouring areas in 2008. This has been the case since 2000. Overall, there was a net generation surplus of 1,028 GWh for the year. **Figure 4** shows the monthly net exchange with neighbouring countries in 2008. Positive values indicate imports to Western Denmark, while negative values are exports out of the area. The physical exchange is stated as hourly mean values based on quarter-hourly registration.

Western Denmark experienced net imports from May to September. Throughout the year, there were net imports from Norway and exports to Germany, while there were net imports from Sweden with the exceptions of August and the last three months of the year.

The Skagerrak 3 interconnection between Western Denmark and Norway was

Figure 3 Net exchange from the East Danish TSO area in 2008. Positive values are imports, negative values exports.

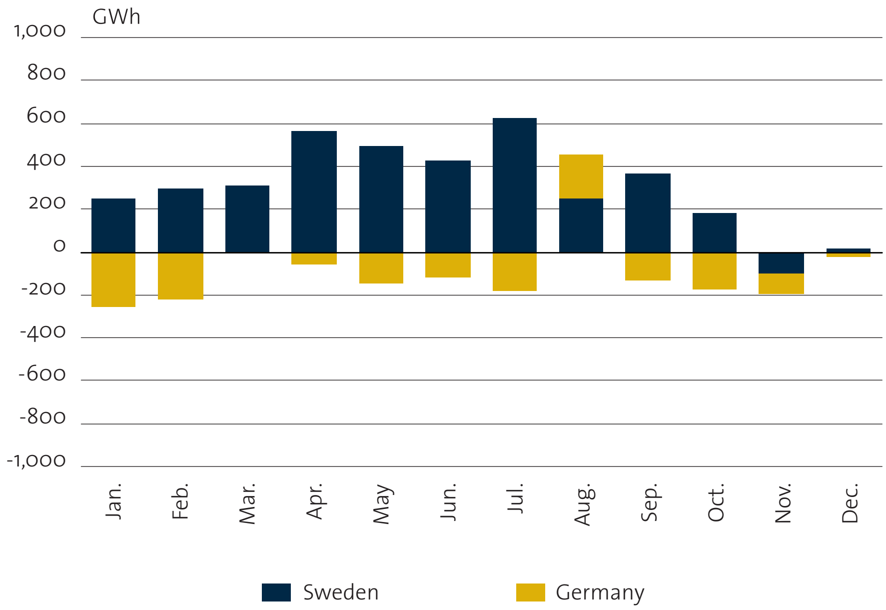
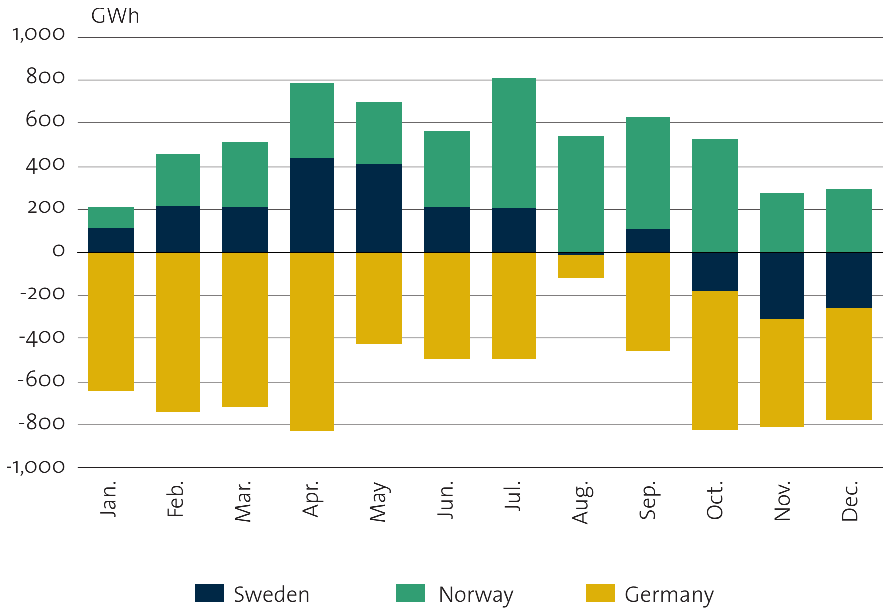


Figure 4 Net exchange from the West Danish TSO area in 2008. Positive values are imports, negative values exports.



recommissioned at the end of June, after an outage time of almost one year due to a transformer breakdown. This increased trading capacity enabled greater imports from Norway in the latter half of 2008.

2.6 Emission of substances subject to the emissions trading scheme in 2008

Electricity and CHP generation is only one of several sources of Danish emissions of air pollutants. However, it contributes primarily to emissions of CO_2, SO_2, and NO_X with a share of total emissions in Denmark of 43%, 40% and 21%, respectively, as shown in **Textbox 1.**

Air pollution from the Danish electricity sector is regulated in connection with the environmental approval of the individual units. Here, a series of executive orders, which relate to specific unit types and pollution parameters, are taken into consideration. The executive order on 'The limitation of emissions of certain air pollutants from large combustion plants' regulates units with a thermal output greater than 50 MW, for example where emission limit values for SO_2 and NO_X are concerned.

The emission of CO_2, SO_2 and NO_X is also subject to emission regulation:

- The Danish CO_2 Emission Allowances Act (no. 493 of 9 June 2004), where the allocation of emission allowances reflects the national allocation plan (NAP).
- The executive order on 'The limitation of emissions of sulphur dioxide and nitrogen oxides from power stations' (Executive Order no. 885 of 18 December 1991) with annual allowances set by the Danish Energy Agency.

The development in emissions from Danish electricity and CHP generation, for the three substances covered by the emissions trading scheme since 1990, can be seen in **Figure 5**. The figure shows a gradually falling trend, especially for SO_2 and NO_X. It also shows how electricity generation and consequent emission levels depend on electricity trading with neighbouring

Textbox 1

Electricity and CHP generation's share of total Danish emissions of pollutants in 2007

The table below shows emissions from the electricity and CHP sector in 2007 compared with total emissions1 in Denmark in 2007. The latest national statement is for 2007, so it is not possible to analyse figures from 2008.

Emissions from the electricity and CHP sector in 2007 compared with total emissions in Denmark[1]

Tonnes	Electricity and CHP sector	Denmark Total$_2$	Share
CO_2 (carbon dioxide – greenhouse gas)	23,140,286	53,227,804	43%
SO_2 (sulphur dioxide)	9,304	23,325	40%
NO_X (nitrogen oxides)	35,434	166,694	21%
CH_4 (methane – greenhouse gas)	11,749	273,695	4%
N_2O (nitrous oxide – greenhouse gas)	378	21,870	2%
NMVOC (unburnt hydrocarbons)	2,843	104,388	3%
CO (carbon monoxide)	7,875	448,135	2%
Particles	937	52,299	2%

[1] Does not include CO_2 absorption in soil and forests
[2] Data collected by the Danish National Environmental Research Institute 2009

The electricity and CHP sector chiefly contributes to CO_2, SO_2 and NO_X emissions with 43%, 40% and 21% respectively. Where the other pollutants are concerned, electricity and CHP generation constitutes only a small percentage (< 5%) of total Danish emissions.

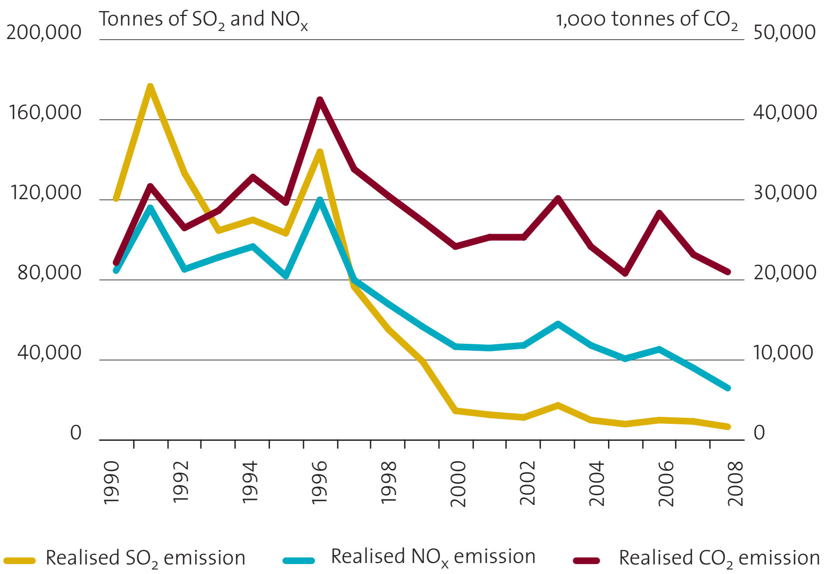
The agricultural sector is the largest source of CH_4 and N_2O emissions. In 2007, agriculture accounted for 67% of total CH_4 emissions and approx. 92% of total N_2O emissions. The second largest source of CH_4 is waste disposal sites. Due to the falling consumption of natural gas in gas engines, the electricity and CHP sector's share of CH_4 emissions is falling.

The transport sector is the largest source of NO_X, accounting for 45% of total emissions in 2007.

The largest source of CO and particles is households, which is mainly due to wood firing. A considerable contribution of CO stems from mobile sources in households. The largest source of NMVOC is the use of solvents (32%), followed by households and the transport sector with 28% and 21% respectively.

In 2008, the electricity and CHP sector is expected to account for a smaller percentage of the total emissions due to reduced electricity exports compared with 2007. With the exception of the transport sector, the emission contribution from other sectors typically varies very little from one year to the next. Assuming that emissions from all other sectors are constant from 2007 to 2008, the electricity and CHP sector will produce 41%, 33% and 16% of the total Danish emissions of CO_2, SO_2 and NO_X respectively.

Figure 5 Emissions of substances subject to the emissions trading scheme from electricity and CHP generation in Denmark..



countries. In particular, it shows an increase in the emission of CO_2, SO_2 and NO_x in the dry years 1991, 1996, 2003 and 2006 because the generation especially from coal-fired power stations is higher in dry years. Consequently, the Danish emissions level is affected by whether it is a wet year or a dry year. The emissions level for 2008 followed the general trend of low emissions during wet years.

In 2008, the actual emission of CO_2, SO_2 and NO_x fell by 5%, 94% and 70%, respectively, from 1990 to 2008. The emission of CO_2 varies substantially from year to year depending on the consumption of fuel at the power stations. The fall in SO_2 emissions can be attributed to the use of fuel with a lower sulphur content and the installation of desulphurisation units at large power stations. NO_x emissions were reduced primarily because of the installation of deNO_x units and low-NO_x burners at large power stations.

The time series in **Figure 5** indicate the realised emissions of CO_2, SO_2 and NO_x. This constitutes Energinet.dk's statement of total realised emissions from electricity and CHP generation in Denmark.

The emissions are also presented in the following section in accordance with the statement methods stipulated by the aforementioned legislation.

2.6.1 CO_2 emission inventory 2008

Since 2000, major Danish power generators (above 25 $MW_{electricity}$) have been participating in a Danish CO_2 emissions trading scheme. On 1 January 2005, the EU Emission Allowance Trading Directive came into force, and the national scheme was abolished.

The aim of the directive is to set a ceiling on CO_2 emissions from the most energy-intensive enterprises within the EU, including all electricity and heat generating facilities with a thermal output of more than 20 MW.

One CO_2 emission allowance allows a power generator to emit one tonne of CO_2. The allocation of CO_2 allowances (free emission allowances) to those enterprises participating in the emissions trading scheme is made on the basis of national allocation plans approved by the European Commission. Enterprises covered by the emission allowance scheme are also permitted to mutually trade allowances, thereby creating a market and a price for CO_2. Enterprises must surrender allowances each year equal to their CO_2 emissions. Enterprises expecting to have insufficient CO_2 allowances to cover their needs must either carry out internal reduction measures or acquire allowances on the market and thus purchase the right to emit more CO_2.

The EU's emissions trading scheme currently comprises three phases. 2005-2007 is considered a trial period. The second phase follows the Kyoto Protocol commitment period, which covers the years 2008-2012. The third phase of the EU's emissions trading scheme is set for a period of eight years from 2013 to 2020.

The trial period of the allowance directive was characterised by an over-allocation of allowances to the sectors covered by the emissions trading scheme. When, during 2006, the market became aware that some EU member states had issued too many allowances compared with the actual requirements of the enterprises, the allowance price quickly dropped to an insignificant level. In Denmark, the total CO_2 emission subject to emission allowances

Table 3 CO_2 emissions from electricity and CHP generation in Denmark in 2008.

CO_2 emissions 2008 calculated in accordance with the Danish CO_2 Emission Allowances Act	Million tonnes of CO_2		
	Eastern Denmark	Western Denmark	Denmark Total
Realised. Electricity and CHP sector	7.0	11.8	18.8
Of which used in connection with electricity generation[1]	5.6	9.5	15.1
Realised. Industrial and service sectors	0.2	0.5	0.7
Realised[2]	0.2	0.6	0.8
Total realised for all units	7.5	12.8	20.3

[1] Calculated in accordance with the Danish CO_2 Emission Allowances Act
[2] Not comprised by the Danish CO_2 Emission Allowances Act

Table 4 SO_2 emissions from thermal electricity generation units in Demark in 2008.

SO_2 emissions in 2008	1,000 tonnes Eastern Denmark	 Western Denmark	 Denmark Total
A: Realised. Units > 25 MW	2.7	2.2	4.9
C: Realised. Units < 25 MW	0.8	1.1	1.9
Total realised for all units	3.6	3.3	6.9

A: Indicates the sum of measured or calculated emissions for units larger than 25 $MW_{electricity}$.
C: Indicates emissions from units smaller than or equal to 25 $MW_{electricity}$.
Any deviations in totals are due to decimal rounding.

was 90 million tonnes for 2005-2007, which is somewhat less than the allocated volume of emission allowances of 93.9 million tonnes.

The costs of CO_2 emission allowances are largely calculated into the total generation costs by the power generators and therefore affect the price of electricity in the same manner as the costs of fuel, eg coal. The transition to the Kyoto period 2008-2012 has resulted in a significant tightening of the allocation of emission allowances in the national allocation plans and thus a considerable increase in the emission allowance price. In 2008, the cost of CO_2 emission allowances constituted on average around one quarter of the total costs of electricity generation at a coal-fired power station.

Denmark has committed to reducing national greenhouse gas emissions from the rate reported for 1990 by 21% during the period from 2008 to 2012. On 31 August 2007, the European Commission approved the Danish allocation plan for the period 2008-2012. The allocation plan documents how Denmark will achieve its reduction commitment. A major change to the new allocation plan is that fewer free allowances are allocated to the electricity and CHP sector. The electricity and CHP sector is granted a total of 15.8 million emission allowances annually, where electricity and heat generators by comparison emitted 21.8 million tonnes of CO_2 per year on average during the trial period.

In Environmental Report 2009, Energinet.dk assesses CO_2 emissions from Danish electricity and CHP generation, as seen in **Table 3**. The table also shows the share of CO_2 emissions attributable to electricity generation under the provisions of the Danish CO_2 Emission Allowances Act. The Danish Energy Agency oversees the enterprises' annual reporting of emissions under the CO_2 Emission Allowances Act, the deadline for such reporting being 31 March. Energinet.dk's assessment of the emission of substances subject to emission allowances is based on preliminary figures obtained prior to the deadline on 31 March 2009.
Realised emissions from the electricity and CHP sector added together with realised emissions from the industrial and service sector give the total emissions from power generators with emission allowances calculated in accordance with the CO_2 Emissions Allowances Act. Total emissions for Eastern Denmark were thus 7.2 million tonnes of CO_2 in 2008. Emissions from power generators with emission allowances in Western Denmark totalled 12.3 million tonnes in 2008. The volume of total free emission allowances was approx. 17.4 million tonnes for electricity and CHP generation in 2008. With total emissions of 19.5 million tonnes in 2008, emissions were higher than the free allowance.

2.6.2 SO_2 emission inventory 2008

Under the Danish executive order on SO_2 and NO_x emission allowances, the SO_2 emission allowance applies solely to emissions of SO_2 from thermal plants larger than 25 $MW_{electricity}$. Emissions of SO_2 from these plants are shown in **Table 4**. The table also shows emissions from units smaller than or equal to 25 $MW_{electricity}$ that are not covered by the emissions trading scheme. In 2008, the realised emission of SO_2 for units covered by the emissions trading scheme was 4,945 tonnes. By comparison, the ceiling for SO_2 emissions was 22,000 tonnes in 2008.

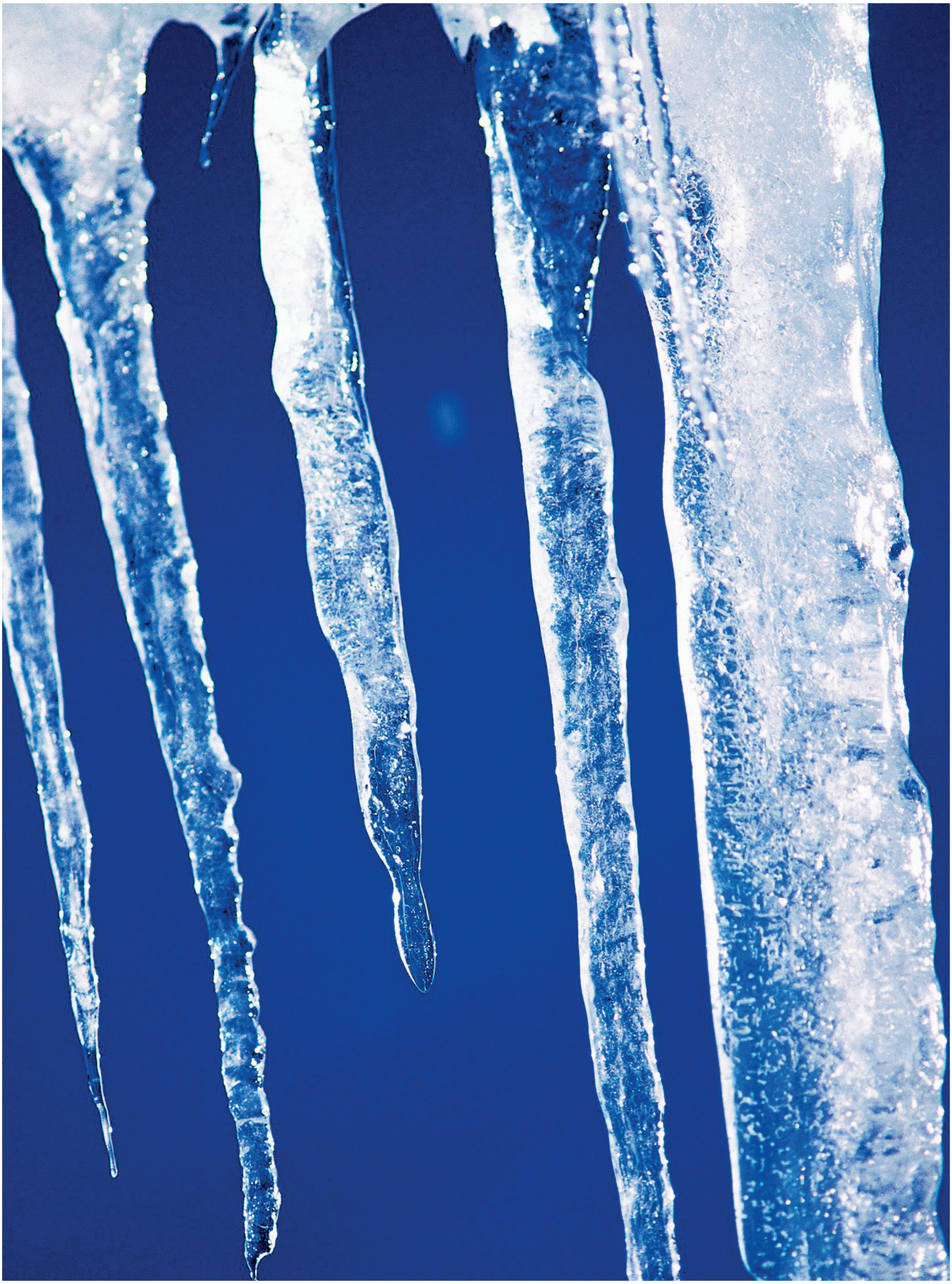
Overall, the emission of SO_2 was 2,379 tonnes lower in 2008 than in 2007. SO_2 emissions from units smaller than or equal to 25 $MW_{electricity}$ was approx. 9% higher in 2008 than in the previous year, and emissions from these units in 2008 constituted around 28% of the total emission.

SO_2 emissions from the units covered by the emissions trading scheme fell by 2,532 tonnes from 2007 to 2008, corresponding to a fall of almost 34%. In Eastern Denmark, reduced generation at central power stations resulted in a fall in SO_2 emissions from units larger than 25 $MW_{electricity}$ by approx. 1,000 tonnes. SO_2 emissions from units larger than 25 $MW_{electricity}$ in

Table 5 NO_x emissions from thermal electricity generation units in Denmark in 2008.

NO_x emissions in 2008	1,000 tonnes Eastern Denmark	 Western Denmark	 Denmark Total
A: Realised. Units > 25 MW	6.5	9.3	15.8
B: Adjusted. Units > 25 MW	8.1	8.7	16.8
C: Realised. Units ffi 25 MW	2.8	7.1	9.9
Total realised for all units	9.3	16.4	25.7

A: Indicates the sum of measured or calculated emissions for units larger than 25 $MW_{electricity}$.
B: Indicates A after adjustment for international electricity exchange. Adjustment is based on the fraction-exchange method.
C: Indicates emissions from units smaller than or equal to 25 $MW_{electricity}$. These are not comprised by the allowance.
Any deviations in totals are attributable to decimal rounding.



Western Denmark fell from 3,710 tonnes in 2007 to 2,210 tonnes in 2008. In Western Denmark, SO_2 emissions in 2008 from units covered by the emissions trading scheme were similar to levels experienced in 2006. The fall in Western Denmark can also be attributed to unusually high SO_2 emissions in 2007, due to substantial generation at Unit 3 at Fyn Power Station, which has no desulphurisation plant.

2.6.3 NO_x emission inventory 2008

Under the executive order on SO_2 and NO_x emission allowances, the NO_x emission allowance applies solely to NO_x emissions from thermal plants larger than 25 $MW_{electricity}$. Emissions in 2008 are shown in **Table 5**. The table also shows emissions from units smaller than or equal to 25 $MW_{electricity}$ that are not covered by the emissions trading scheme. In contrast to the emission allowance regulation of SO_2, the emission of NO_x can be adjusted for international exchange.

Realised NO_x emissions from electricity and CHP generation in Denmark fell by approx. 10,000 tonnes from 2007 to 2008. Emissions from smaller plants have primarily been constant for the period, while the contribution from plants not covered by the emissions trading scheme to the total NO_x emission increased from 28% in 2007 to 39% in 2008.

In Eastern Denmark, NO_x emissions from plants covered by the emissions trading scheme fell by 1,758 tonnes from 2007 to 2008. With a total fall of 8,174 tonnes or almost 47%, the plants covered by the emissions trading scheme in Western Denmark had the greatest impact on the low NO_x emissions result in 2008. The fall in Western Denmark is due to the commissioning of deNO_x facilities at Studstrup Power Station and Unit 3 at Fyn Power Station at the end of 2007 as well as an overall fall in generation from plants larger than 25 $MW_{electricity}$ without deNO_x facilities. If the adjusted NO_x emissions in **Table 5** are compared with the allowance allocation for 2008 of 22,000 tonnes, it becomes apparent that the allowance has been observed within a margin of approx. 5,000 tonnes. However, it should be noted that the NO_x emissions have been adjusted for imports/exports based on the fraction method, while in conformity with last year, the Danish Energy Agency allowed freedom in the choice of adjustment method. This means that it is also possible to apply the zero-exchange method. The background report to Environmental Report 2009 explains both methods.

In recent years, the Danish executive order on emission allowances has placed great demands on the plants covered by the emissions trading scheme to limit their NO_x emissions. Consequently, the executive order has been one of the main reasons for the reduction in exchange-adjusted NO_x emissions from large power generators to 16,762 tonnes in 2008 from 30,373 tonnes in 2005, 26,922 tonnes in 2006 and 24,037 tonnes in 2007. With the application of stricter emission limit values on NO_x emissions for large plants from 1 January 2008, it can be concluded that fixed ceilings for emission allowances in the executive order have no longer any effect on the emission of NO_x from plants larger than 25 $MW_{electricity}$.

In accordance with the EU NEC Directive for national emission ceilings, Denmark is under an obligation to reduce total Danish NO_x emissions to 127,000 tonnes per year in 2010. Forecasts have previously indicated that Danish NO_x emissions will exceed the ceiling for emissions in 2010, unless additional means are applied. Therefore, as a part of the Danish energy agreement of 21 February 2008, a NO_x tax of DKK 5 per kg will be in force as of 1 January 2010 and apply to all plants. The introduction of the NO_x tax will also mean that the Danish executive order on SO_2 and NO_x emission allowances will be repealed.

2.7 Energinet.dk – environmental improvements in the energy sector

Emission factor update

Calculations of environmental impacts from the electricity and CHP sector, including for this Environmental Report, are largely based on emission factors. The factors are verified by the National Environmental Research Institute in Denmark (DMU) at the University of Aarhus. A joint PSO R&D project was implemented in 2002-2003 with a view to updating the emission factors for local CHP plants, see also www.energinet.dk under R&D and PSO project 3141. Energinet.dk has decided to ensure further expansion and qualification of emission factors. In 2007, a new project was launched in collaboration with the Danish Gas Technology Centre (DGC) and the DMU. This project will contribute to making Danish emission factors even more accurate and comprehensive, so we can retain our leading position in the world market. The project will collect additional, more accurate data, for example on emissions of heavy metals. The project is expected to conclude in 2010, and the new data will be converted to emission factors at the DMU and form part of the calculations for the Environmental Report 2011.

Magnetic Fields Committee

The Magnetic Fields Committee of the Danish electricity companies collects and distributes relevant knowledge within the area. The Committee's work is financed by Energinet.dk. The Magnetic Fields Committee publishes a newsletter and other information material as required. For further information, see www.energinet.dk.

Life cycle analysis of Danish electricity and CHP

In collaboration with DONG Energy and Vattenfall, Energinet.dk has started updating a life cycle analysis (LCA) project from 1997-2000. The objective of the project is to describe environmental impacts of Danish electricity and CHP from fuel to consumption in 2008.

Reduction of transmission losses through optimised voltage control

Energinet.dk and Aalborg University are collaborating on a project to minimise the transmission losses. The primary focus of the project is optimum voltage control of the electricity transmission grid, including optimisation of the reactive power compensation of the power grid. The project is based on the mapping and analysis of current transmission loss levels with a view to identifying immediate measures to reduce transmission losses and ensure general operations optimisation. In connection with the project, a few sections in the 150 kV transmission grid were selected where it was economically profitable to install another type of conductor, which has a lower loss. A fall in transmission losses will result in operational savings and the added environmental benefit of reducing the volume of electricity generation needed to cover transmission losses.

Strategic environmental assessment

In 2008, Energinet.dk in collaboration with Aalborg University initiated a PhD project for strategic environmental assessment (SEA) in the energy sector. SEA is a statutory requirement for a broad portfolio of plans and programmes in the energy sector, among other sectors. The objective of SEA is to contribute to the integration of environmental considerations during the drafting and adoption of plans and programmes with a view to advancing sustainable development. The expected comprehensive changes to the energy systems in the coming years underscore the importance of integrating environmental considerations into decision-making processes, and thus SEA is expected to be an essential tool in future. On a national level, a SEA entitled 'Future Offshore Wind Turbine Locations' has been prepared, and Energinet.dk has started a SEA for the development of the gas infrastructure and similarly plans to prepare a SEA for the planning of the electricity infrastructure.

Corporate Social Responsibility

In 2008, Energinet.dk committed to starting a Corporate Social Responsibility (CSR) project. CSR incorporates those initiatives that enterprises voluntarily implement concerning social, ethical and environmental conditions. Climate and environment will be one of the focus areas of Energinet.dk's CSR in the future. The objective will be to minimise Energinet.dk's energy consumption and manage operations, maintenance and the expansion of the infrastructure in an environmentally and socially optimal manner.

3. Denmark survey 2008

Table 6 shows a survey of key figures for electricity generation, fuel consumption and environmental impacts in 2008. The figures represent Eastern and Western Denmark and Denmark as a whole. The survey includes a number of explanatory notes on the methods used. See the notes below.

Note 1. Gross electricity generation corresponds approximately to the power supplied by the generator at the individual production units. Part of the gross generation is consumed before delivery to the grid. This applies, for example, to the power station's internal consumption for the operation of pumps, coal mills, environmental installations, magnetisation, etc. The internal consumption of enterprises covered by the rules on net settlement is included in the gross statement.

Note 2. Electricity supply is the amount of electricity from production units available for domestic consumption or export via the grid. Electricity supplies are measured physically upon discharge from individual production units and are registered in Energinet.dk's PANDA database. Electricity supplies are based on a system balance calculated in January of the year following the statement year.

Note 3. CHP generation comprises the gross heat generation. No distinction is made between heat used for internal industrial processes, process steam production or sold as district heating.

Note 4. Imports and exports are stated as cross-border net exchange. The figures are the sum of all recorded net values during the year. Net values are calculated for each interconnection. The basis is a one-hour average in Eastern Denmark and a fifteen-minute average in Western Denmark.

Note 5. These losses concern the transmission grid (400 kV, 150 kV and 132 kV) and the HVDC substations in interconnections. Transit losses from interconnections are included in these losses.

Note 6. These losses concern local distribution networks (60 kV and below), which are operated by local grid companies. Each distribution network has an individual loss percentage. The calculation is based on an estimated average loss of 5%.

Note 7. Domestic consumption including losses in the transmission grid and distribution networks. In areas with net exports, this figure covers electricity supplies less net exports out of the area. In areas with net imports, this figure covers electricity supplies plus net imports.

Note 8. Under the Danish CO_2 Emission Allowances Act, waste is considered CO_2 neutral. However, waste contains large volumes of plastic, which is produced from fossil fuels such as oil. In accordance with the Danish executive order on guarantees of origin for RE electricity, a 80/20 distribution between biodegradable and plastic-containing parts in waste is applied. Consequently, 80% of the waste is considered CO_2 neutral. For calculation purposes, this corresponds to using an emission factor of 17.6 kg/GJ for waste.

Note 9. Other desulphurisation products include SDAP and gypsum filter cake. Most of the SDAP produced is reused by other power stations and converted into gypsum at the wet desulphurisation plants. The volume stated is the volume produced.

Note 10. Fly ash, flue-gas cleaning products, filter cake, wastewater sludge, etc. are classified as hazardous waste and are currently being deposited in Germany or Norway.

Note 11. Comprises carbon dioxide, methane [21], dinitrogen oxide [310] and SF_6 gas [23,900]. The figure in square brackets is the equivalency factor for conversion into CO_2 equivalents.

Tabel 6 Denmark survey 2008.

Denmark survey 2008	Note	Unit	Eastern Denmark	Western Denmark	Denmark Total
Electricity generation (gross generation, incl. own consumption)	1	GWh	12,796	23,927	36,723
Electricity supply to the grid (net ex plant)	2	GWh	12,001	22,648	34,649
CHP generation	3	TJ	43,731	66,889	110,620
Electricity imports	4	GWh	4,949	7,769	12,718
Electricity exports	4	GWh	2,467	8,797	11,264
Losses in transmission grid (AC and DC)	5	GWh	359	518	877
Domestic generation for resale		GWh	11,642	22,129	33,772
Losses in distribution network	6	GWh	706	1,055	1,761
Consumption (sale to transmission grid)		GWh	14,483	21,620	36,103
Consumption (sale to distribution network)		GWh	14,124	21,102	35,226
End consumption (sale to consumer)	7	GWh	13,418	20,046	33,464
Specification of net electricity generation					
Electricity from land-based wind turbines		GWh	1,068	4,386	5,453
Electricity from offshore wind turbines		GWh	718	806	1,524
Electricity from hydropower and photovoltaics		GWh	0	27	27
Electricity from biofuels		GWh	1,054	866	1,920
Electricity from waste		GWh	619	1,053	1,672
Electricity from natural gas		GWh	2,664	4,373	7,038
Electricity from oil		GWh	668	218	886
Electricity from coal		GWh	5,210	10,919	16,129
Emissions to air from electricity and CHP generation					
CO_2 (carbon dioxide – greenhouse gas)	8	tonnes	7,724,202	13,286,795	21,010,997
SO_2 (sulphur dioxide)		tonnes	3,550	3,334	6,885
NO_x (nitrogen oxides)		tonnes	9,349	16,366	25,715
CH_4 (methane – greenhouse gas)		tonnes	2,876	9,028	11,904
N_2O (dinitrogen oxide – greenhouse gas)		tonnes	144	208	352
NMVOC (unburnt hydrocarbons)		tonnes	770	2,161	2,930
CO (carbon monoxide)		tonnes	2,585	4,969	7,554
Particles		tonnes	200	629	829
Fuel consumption for electricity and CHP generation - mass					
Coal		tonnes	2,258,928	4,428,607	6,687,535
Oil		tonnes	205,471	92,909	298,380
Natural gas, incl. refinery gas		1,000 Nm^3	728,067	1,095,733	1,823,800
Biofuels		tonnes	784,093	968,670	1,752,763
Waste		tonnes	1,452,176	1,772,164	3,224,340
Fuel consumption for electricity and CHP generation – calorific value					
Coal		TJ	54,572	108,288	162,860
Oil		TJ	8,360	3,789	12,149
Natural gas, incl. refinery gas		TJ	28,797	43,403	72,199
Biofuels		TJ	11,883	13,218	25,100
Waste		TJ	15,248	19,897	35,145
Residual products from electricity and CHP generation					
Coal fly ash		tonnes	264,938	518,166	783,104
Coal slag		tonnes	35,602	52,836	88,438
Gypsum		tonnes	81,453	94,931	176,384
Other desulphurisation products (SDAP)	9	tonnes	0	56,172	56,172
Bio ashes		tonnes	25,017	23,083	48,099
Slag (waste incineration)		tonnes	268,348	341,844	610,192
MSWI-ACP residues	10	tonnes	48,558	49,069	97,627
Specification of CO_2 emissions					
A: CO_2 from electricity and CHP (waste not considered CO_2 neutral)	8	mil. tonnes	7.7	13.3	21.0
B: CO_2 from electricity and CHP (waste considered CO_2 neutral)	8	mil. tonnes	7.5	12.9	20.4
C: CO_2 equivalents from electricity and CHP (waste considered CO_2 neutral)	8, 11	mil. tonnes	7.6	13.2	20.8
D: CO_2 from electricity (waste not considered CO_2 neutral. Allocation at 125% thermal efficiency)	8	mil. tonnes	6.0	10.2	16.2
E: CO_2 from electricity (waste considered CO_2 neutral. Allocation at 125% thermal efficiency)	8	mil. tonnes	5.9	10.1	15.9
Specification of SO_2 and NO_x emissions. Totals for electricity and CHP generation					
SO_2 from units ≤ 25 $MW_{electricity}$		1,000 tonnes	0.8	1.1	1.9
SO_2 from units >25 $MW_{electricity}$		1,000 tonnes	2.7	2.2	4.9
Total SO_2 emissions. Not adjusted for international exchange		1,000 tonnes	3.6	3.3	6.9
NO_x from units ≤ 25 $MW_{electricity}$		1,000 tonnes	2.8	7.1	9.9
NO_x from units > 25 $MW_{electricity}$		1,000 tonnes	6.5	9.3	15.8
Total NO_x emissions. Not adjusted for international exchange		1,000 tonnes	9.3	16.4	25.7

4. Environmental Impact Statement for electricity

Energinet.dk prepares annual Environmental Impact Statements for electricity supplied in Eastern and Western Denmark respectively. There are two main types of statements: an Environmental Impact Statement and an Electricity Label.

- The Environmental Impact Statement describes the environmental impact of the supply of one kWh of average electricity. Transmission losses are included and adjusted for electricity exchanges with neighbouring countries. The Environmental Impact Statement is chiefly used by public and private enterprises in their environmental efforts.
- The Electricity Label is prepared on the basis of a statutory requirement, which obliges electricity traders to provide information about the fuel mix and environmental conditions associated with the generation of the electricity that they sell to their customers. The Electricity Label is available in two types: a general label for average electricity and an individual label for electricity with a special environmental profile.
- This chapter describes the Environmental Impact Statement and the Electricity Label for 2008. The most significant changes to the statement and label from 2007 to 2008 are described, and an account is given of the fuel distribution, related emissions and residual products from the consumption of one kWh of electricity in 2008.

4.1 Environmental Impact Statement for electricity 2008

The consumption of electricity and the resulting emissions to the environment contribute markedly to the environmental impact from enterprises and industry. The Environmental Impact Statement for electricity is thus widely used in the environmental activities of public and private enterprises.

As there is no direct grid connection between Eastern Denmark and Western Denmark, Energinet.dk has chosen not to prepare a joint impact statement for the two areas. Furthermore, operating conditions and generation capacity differ in the two system areas. For the time being, the individual Environmental Impact Statements for Eastern and Western Denmark are thus prepared separately. Energinet.dk does not expect to calculate an impact statement for Denmark as a whole until the Great Belt Power Link is established in autumn 2010. This will come into effect as of Environmental Report 2011.

The Environmental Impact Statement for electricity supplied for consumption in 2008 in Eastern Denmark and Western Denmark, respectively, can be seen in **Table 7**. The environmental Impact Statements are provided with an auditor's report and were published on Energinet.dk's website on 27 February 2009.

The Environmental Impact Statement describes how much CO_2, CO, CH_4, N_2O, SO_2, NO_X and NMVOC (unburnt hydrocarbons) is emitted and how many particles are generated by the consumption of one kWh of electricity. Fuel consumption and residual products are also stated per kWh. The greenhouse gases CO_2, CH_4 and N_2O are shown jointly as greenhouse gases stated as CO_2 equivalents.

Danish electricity generation can be divided into power stations, local CHP plants and wind turbines. Local CHP plants have a different environmental profile than the power stations, which is primarily attributable to differences in fuel consumption, efficiency, combustion technology and the extent of flue gas treatment. The power stations use mostly coal and to a lesser degree natural gas, biomass and oil. Most local CHP plants are fuelled by natural gas but some local CHP plants are also based on waste, biomass, biogas and oil. Emissions of CO_2, SO_2 and particles stem primarily from the power stations. Similarly, local CHP generation is the primary source of CH_4 and NMVOC emissions. In relation to the remaining emissions, local CHP plants have on average higher emissions per generated kWh than power stations, while the absolute contribution to emissions of the substances concerned is more equally distributed.

A large proportion of Danish thermal electricity generation occurs at facilities generating both electricity and heat.

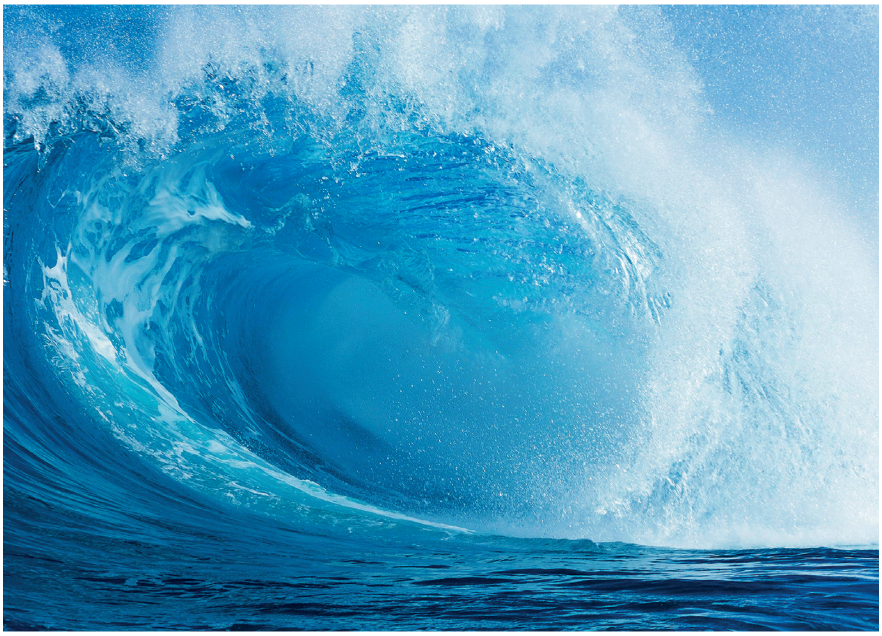
Table 7 Environmental Impact Declaration 2008 for electricity for consumption in Eastern and Western Denmark. Figures are stated according to the 125% and 200% thermal efficiency methods. For 2008, the 125% calculation method applies.

Environmental Impact Statement for electricity supplied for consumption in 2008		Eastern Denmark		Western Denmark	
		125%	200%	**125%**	200%
Emissions to air	**g/kWh**				
CO_2 (carbon dioxide – greenhouse gas)		**429**	475	**449**	500
CH_4 (methane – greenhouse gas)		**0.12**	0.16	**0.25**	0.32
N_2O (dinitrogen oxide – greenhouse gas)		**0.008**	0.009	**0.006**	0.007
Greenhouse gasses total (CO_2 equivalents)		**434**	481	**457**	509
SO_2 (sulphur dioxide)		**0.18**	0.21	**0.09**	0.11
NO_X (nitrogen oxide)		**0.47**	0.54	**0.47**	0.57
CO (carbon monoxide)		**0.15**	0.17	**0.14**	0.17
NMVOC (unburnt hydrocarbons)		**0.04**	0.04	**0.06**	0.08
Particles		**0.01**	0.01	**0.02**	0.02
Residual products	**g/kWh**				
Coal fly ash		**16.2**	17.1	**18.5**	20.0
Coal slag		**2.0**	2.2	**1.8**	2.0
Desulphurisation products		**4.9**	5.2	**5.5**	5.9
Slag (waste incineration)		**8.4**	12.4	**7.8**	10.9
MSWI-ACP residues		**1.5**	2.2	**1.2**	1.6
Bio ashes		**1.2**	1.4	**0.6**	0.8
Radioactive waste (mg)		**0.1**	0.1	**-**	-
Fuels	**g/kWh**				
Coal		**138**	146	**158**	171
Oil		**10**	12	**2**	3
Natural gas		**25**	31	**26**	32
Biofuels		**38**	45	**23**	31
Waste		**45**	67	**41**	57
Nuclear power (mg uranium)		**0.21**	0.21	**-**	-
Lignite		**-**	-	**-**	-
Other fuels (oil equivalent)		**0.8**	0.8	**-**	-

Table 7 shows the Environmental Impact Statement calculated using two different methods for distributing the environmental impact of the cogeneration of electricity and heat. Both methods are based on the so-called thermal efficiency method, which assumes that heat is generated with a given thermal efficency (efficiency when converting fuel to heat). One of the methods assumes a thermal efficiency of 200% and this was used to prepare Environmental Impact Statements up to and including 2005. The other method assumes a thermal efficiency of 125% and is upon recommendation of the Danish Energy Agency the method used by Energinet.dk as of 2006. The transition to using the 125% method harmonises with the method used for allocating CO_2 emission allowances. The background report to Environmental Report 2009 explains both methods in detail.

The following explanation of changes in the Environmental Impact Statement from 2007 to 2008 is based on a comparison between the Environmental Impact Statements prepared in accordance with the 125% method.

The values of the Environmental Impact Statement depend not only on the choice of distribution key between electricity and heat but also on other method-related factors. In connection with the Environmental Impact Statement for electricity consumed in Eastern and Western Denmark, it is necessary to adjust the areas' generation



for electricity exchanged with neighbouring areas. The adjustment for exchange is made according to the following principle: Firstly, wind power is allocated for Danish consumption. Secondly, local electricity generation is allocated. Electricity generation from power stations is also included under consumption, but if annual domestic generation exceeds consumption, the surplus power station generation is exported. If generation is lower than consumption, the generation deficit is covered by imported electricity.

Only in years with net imports will imported electricity from neighbouring countries be included in the Environmental Impact Statement. The impact statement for electricity imported from our neighbouring countries Sweden, Norway and Germany is based on the average values for electricity generation in these countries. 2008 saw net imports of electricity to Eastern Denmark but net exports of electricity from Western Denmark. Therefore, **Table 7** includes a contribution from nuclear power, for instance, in the impact statement for Eastern Denmark due to net imports from Sweden.

The environmental impact of consuming one kWh of electricity in a given year, apart from environmental improvement initiatives taken at individual power stations, will depend on the relative generation contribution from power stations, local CHP plants and wind turbines as well as the share of electricity imported from our neighbouring countries.

In 2008, wind power generation in Western Denmark was approx. 7% lower than in 2007 due to less favourable wind conditions. Despite the less favourable wind conditions, wind generation in Eastern Denmark increased for the same period, which can be explained by a prolonged breakdown at Nysted wind farm in 2007. After some years of falling generation from local CHP plants, following the transition to market conditions, generation from local CHP plants remained generally unchanged between 2007 and 2008 in both Eastern and Western Denmark. In 2008, local CHP plants constituted 14% of consumption in Eastern Denmark compared with 22% in Western Denmark.

In 2008, generation from power stations accounted for approx. 55% of the electricity consumed in both Eastern and Western Denmark. The share of electricity consumption in Western Denmark generated by power stations increased 2 percentage points from 2007 to 2008, while increased imports from Sweden to Eastern Denmark resulted in a significant fall in power station generation in this area. Imported electricity thus covered 17% of Eastern Denmark's electricity consumption in 2008 compared with 6% in the previous year. The increased import of Swedish electricity with a low CO_2 impact contributed to a reduction of 429 g/kWh in CO_2 emissions per consumed kWh of electricity in 2008 against 543 g/kWh in 2007 and 586 g/kWh in 2006. Because of this import, CO_2 emissions from electricity consumption in 2008 were lower in Eastern Denmark than in Western Denmark.

4.2 Special conditions in Eastern Denmark

In 2008, the fuel mix for one kWh of average electricity in Eastern Denmark was 35% coal, 19% natural gas, 13% waste, biomass and biogas, 20% wind, hydro and solar power, 5% oil and 8% nuclear power.

In 2008, generation in Eastern Denmark fell by 12% compared to 2007, while imports from Sweden rose correspondingly. The fall in generation is especially large at the coal-fired power stations where the share of coal was reduced from 48% in 2007 to 35% in 2008. By comparison, imported electricity from Sweden has a lower environmental impact than the thermally generated electricity in Denmark because Sweden's generation system is dominated by emission-free technologies like hydropower and nuclear power. Consequently, the 2008 Environmental Impact Statement generally shows a falling trend for the stated emissions to air in relation to 2007. The only exception is the emission of CO, where imported electricity has a relatively high emission per kWh. At the same time, there was a significant increase in the share of electricity consumption based on wind, hydro, solar and nuclear power. In 2008, 8% of the electricity consumption in Eastern Denmark was covered by nuclear power, against 3% in the previous year.

In addition to the considerable drop in CO_2 emissions per consumed kWh electricity in Eastern Denmark, there was a significant fall in emissions of the substances SO_2 and NO_x, which are subject to the emission allowances. The lower emission of acidifying gases is primarily due to a fall in generation from the power stations. Moreover, several large facilities have implemented measures to observe the stricter emission requirements of the executive order for large combustion plants, applicable from 1 January 2008. In particular, Stigsnæs Power Station Unit 1 and Asnæs Power Station Unit 4 were decommissioned in the course of 2008 because they were unable to observe the stricter emission requirements.

4.3 Special conditions in Western Denmark

In 2008, the fuel mix for one kWh of average electricity in Western Denmark was 46% coal, 20% natural gas, 9% waste, biomass and biogas, 24% wind, hydro and solar power and 1% oil.

Energy sources used in the generation of electricity for consumption in Western Denmark generally remained unchanged from 2007 to 2008. The contribution of non-thermal renewable electricity (wind, hydro and solar) dropped from 26% to 24% due to a fall in wind turbine generation. The fall in wind power's share of consumption has instead been covered by the fossil fuels coal and natural gas, which resulted in a minor increase in CO_2 emissions.

Regarding the emissions of SO_2 and NO_X, the Environmental Impact Statement for electricity in Western Denmark follows the same downward trend as in Eastern Denmark. NO_X emissions fell from 0.71 g/kWh in 2007 to 0.47 g/kWh in 2008. This considerable fall in NO_X emissions is primarily attributable to the implementation of reduction measures at the large power stations. In particular, the establishment of deNO_X facilities at Studstrup Power Station and Fyn Power Station Unit 7 towards the end of 2007 has contributed significantly to the reduction in NO_X emissions from Western Denmark's power system. The drop in SO_2 emissions is primarily due to extraordinarily large SO_2 emissions in 2007 because Fyn Power Station Unit 3 , which is not equipped with a desulphurisation unit, was in operation for a number of hours during 2007. At the same time, Unit 7, which is equipped with an effective desulphurisation system, was out of operation for a long period.

4.4 Inclusion of transmission and distribution losses

Electricity is transmitted in the high-voltage grid from the generation at a power station to consumption at the customer's premises. In Eastern Denmark, the voltage levels are 400-132 kV in the transmission grid and 50-0.4 kV in the distribution network. In Western Denmark, the voltage levels are 400-150 kV in the transmission grid and 60-0.4 kV in the distribution network. Transmission losses are included in the Environmental Impact Statement for electricity. Transmission losses are approx. 1-2%. This means that the power stations must generate a greater amount of electricity than is supplied to the customers. All end customers purchase electricity from the distribution network. Energy losses in the distribution network vary geographically, and there can be a significant difference between grid companies primarily supplying electricity to urban or rural areas.

Consequently, Energinet.dk recommends that corrections be made for distribution losses by obtaining information about the magnitude of the losses from the relevant distribution system operator. If such information is not available, Energinet.dk suggests using an average figure of 5%. See the calculation example in **Textbox 2.**

Textbox 2

Inclusion of distribution losses

For its environmental report, an enterprise in Western Denmark wants to calculate the CO_2 emissions caused by its electricity consumption. The enterprise consumes 100,000 kWh of electricity per year and has not entered into any agreement for the supply of electricity with special (environmental) properties. The local grid company has stated that the distribution losses constitute 5% of the input energy.

Energinet.dk's Environmental Impact Statement for Western Denmark shows that CO_2 emissions in 2008 totalled 449 g/kWh for electricity supplied from the transmission grid. The enterprise can then calculate its CO_2 emissions by divid-ing the stated emission by a factor of 0.95, thus including distribution losses. This corresponds to emissions in 2008 of:

100,000 kWh x 449 g/kWh/0.95 = 47.3 tonnes of CO_2

4.5 Electricity Label 2008

In pursuance of the Danish executive order on electricity labelling, electricity traders are obliged to prepare electricity labels for the electricity they supplied to end users in the previous calendar year. This means that electricity traders must state the fuel mix and environmental impacts associated with the generation of the electricity they sell to their customers.

Electricity traders must use either a general label or an individual label. The general label is used for common electricity supplies - ie average electricity supplied from the grid. The individual label is used for labelling electricity with specific environmental properties such as electricity generated from renewable energy sources. Energinet.dk has developed a standard form to communicate both the general and the individual label to the consumers.

The general label is prepared by Energinet.dk and placed at the disposal of the electricity traders. However, electricity traders are responsible for preparing individual labels themselves on the basis of guidelines drafted by Energinet.dk.

General label

Each year, Energinet.dk publishes a general label for electricity customers in Eastern and Western Denmark by 1 April at the latest. The general label is calculated on the basis of the electricity generation in the previous calendar year according to the same principles as the annual Environmental Impact Statements for electricity. Transmission and distribution losses are included in the label.

The 2008 label for Eastern and Western Denmark, respectively, was published on Energinet.dk's website on 23 March 2009.

Individual label
Electricity traders can freely choose to market electricity products with a special environmental profile - in the following called individual electricity products. As of the calendar year 2006, however, electricity traders marketing this type of electricity products have been under an obligation to prepare individual labels. Moreover, electricity traders are required to document the information in the individual labels. Guidelines for preparing individual labels are available at www.energinet.dk.

The sale of individual electricity products based on renewable energy (RE) sources or highly efficient CHP requires documentation in the form of guarantees of origin. This proves that the electricity supply is produced by means of a specific environmentally friendly generation method. The guarantee is made in the form of a certificate issued by Energinet.dk.

The sale of individual electricity products has risen steadily over the past few years. In 2006, a total of 100 GWh of this type of electricity products were sold to end customers. In 2007, electricity sales increased to approx. 170 GWh. In 2008, electricity sales grew extensively to approx. 550 GWh, corresponding to approximately 1.6% of the total end consumption in Denmark. Individual electricity products are currently offered to Danish electricity customers as either Danish wind power or Norwegian hydropower. Hydropower dominates the market with a share of around two-thirds of the sales in 2008.

The need to develop electricity labelling
Electricity Labels are prepared in pursuance of the guidelines described in the Danish executive order on electricity labelling. In relation to both the individual label and the general label, it is however possible to identify significant issues that need to be addressed in the future. Issues pertaining to the individual label primarily concern the marketing and environmental value of this type of electricity products, whereas the development potential of the general label largely relates to the calculation methods and data basis.

In recent years, the marketing of individual electricity products by electricity traders has been subject to some criticism, as the consumer's purchase of these types of products neither provides a guarantee of environmental improvements in the short term or future expansion based on renewable energy. Consequently, individual electricity traders have voluntarily begun marketing electricity products which to a higher degree fulfil the electricity customer's desire to make an extra effort for the environment. Either by guaranteeing that a share of the income derived from the customer's purchase of the electricity product goes to financing new RE capacity or, more pervasively, by focusing on reducing the electricity customer's CO_2 emissions from electricity consumption through the cancellation of CO_2 emission allowances.

A variety of such electricity products that offer a guaranteed environmental effect already exist on the market today. However, there is a general need to ensure the credibility of this type of electricity products and not least improve the consumer's possibility of distinguishing between the environmental virtues of the products. A working group under Dansk Elhandel (Association of Danish Electricity Traders) has therefore started to develop a Danish standard for 'green' electricity products. Energinet.dk has actively contributed to this work, which is expected to be completed in 2009.

Another criticism of the Danish system for electricity labelling is that the general label cannot be adjusted for the sale of individual electricity products. Thus problems of double counting arise for electricity supplies from types of generation with a high market value (RE electricity) - that is to say, the same amount of electricity is sold

several times over. The new RE directive includes just such a requirement that the general label effective from the sale of electricity as of 2010 must be calculated as a so-called 'residual mix', which represents the electricity generation that is not sold as individual electricity products.

Energinet.dk has previously participated in the pan-European E-track project, the objective of which was to make recommendations for a common European standard for the labelling of electricity. Based on these recommendations, it becomes apparent that the calculation of a residual mix will require considerable changes to the principle for calculating the general label. In particular, there will be a greater need to harmonise the data basis and calculation methods with neighbouring countries. At the same time, the transition to the calculation of a residual mix will require amendments of the Danish executive order on electricity labelling which are expected to be implemented in the middle of 2010. In the meantime, Energinet.dk will further develop the method for calculating the general label.

5. Environmental impacts 1990-2020

In this chapter, historical environmental impacts in the period 1990-2008 are compared with forecasts up to 2020. It describes developments in electricity consumption, electricity generation, fuel consumption, CO_2 emissions, SO_2 emissions and NO_x emissions. In addition, the background report to Environmental Report 2009 contains forecast estimates for greenhouse gases CH_4 and N_2O, including emissions of CO, NMVOC and particles. There is also a statement of the generation of residual products.

The historical period is set to start in 1990 as this is the reference year for the Kyoto targets. The end of the forecast period is set for 2020 with a view to enabling the assessment of the development in relation to the EU's 2020 targets. The forecast period covers both the first and second Kyoto Protocol commitment periods, ie Kyoto I from 2008 to 2012 and Kyoto II, which is expected to run from 2013 to 2020.

Forecasts for the environmental reports were previously created on the basis of two different price scenarios of high and low electricity prices on the market. For Environment Report 2009, a single price scenario has been selected. Another significant difference compared to the forecasts from Environmental Report 2008 is the preconditions concerning the development in Danish electricity consumption. Apart from the projections for classic electricity consumption, preconditions are also included for a significant expansion based on heat pumps and electric vehicles.

Classic electricity consumption is the term used for electricity consumption as it is known today. A large proportion of new electricity consumption is expected to replace other energy sources in the future. The new energy consumption will benefit the total climate accounts, provided that it manages to exploit the increasing amounts of wind power while replacing fossil fuels outside the scope of the sector subject to allowances. Some examples of this include individual heat pumps in private households to replace oil-fired burners, electric vehicles to replace petrol and diesel-fuelled vehicles in the transport sector and large heat pumps to replace other heat resources in the district heating sector.

The completed simulations are based on a series of preconditions relating to the development of generation technologies, electricity and heat consumption including fuel, CO_2 and electricity prices. These preconditions are summarised in the following section, while a more detailed description of the forecast preconditions can be found in the background report to Environmental Report 2009.

5.1 Analysis of the electricity and heat supply systems

The 2009-2020 forecasts are based on analyses conducted using Energinet.dk's modelling tool SIVAEL (simulation of heat and electricity). The programme optimises the operation of power stations and CHP plants on an hourly basis over the year, assuming normal temperature and climate conditions. The simulations take into account the physical infrastructure at the plants and optimise them on the basis of price signals, which means that the most economical plants generate the required electricity and heat. In the calculations, wind turbine generation is guaranteed to be sold as the generation price is set to zero.

Forecast calculations have been completed for each of the two Danish system areas separately, and the results have then been aggregated to provide a general picture for Denmark. The simulations also take into account exchange with the neighbouring areas and the effect of a power link across the Great Belt connecting the grids in Eastern and Western Denmark from 2010 onwards. The market price in the Nordic region and Germany determines the volume of exports and imports within the framework of interconnection capacities.

The expansion of heat pumps and electric vehicles in the forecast period is based on the preconditions set out in Energinet.dk's analysis 'Effective use of wind-power based electricity in Denmark - Interaction between wind power, heat pumps and electric vehicles'. The analysis is based on a scenario for 2025, which assumes that 15% of the heat requirements in the district heating sector is covered by heat pumps, and 50% of the heat requirements outside the district heating sector is covered by individual heat pumps. This implementation is expected to occur gradually, so that approx. two-thirds of the expansion of heat pumps is completed by 2020. The total electricity consumption by electric vehicles in 2020 is set to 1.4 TWh, equivalent to electric vehicles constituting 10% of all vehicles in Denmark.

5.2 Generation, consumption and exchange; history and forecast

Developments in actual and future electricity consumption are calculated in different ways and using various methods. Energinet.dk calculates the measured electricity consumption at system level, which covers the total electricity consumption in Denmark, excluding transmission and distribution losses. The projection for Danish electricity consumption builds on a model for how electricity consumption in different sectors is going to develop. The model considers, for instance, the expectations for economic growth and improvements in efficiency for the individual sectors.

The electricity consumption panels are selected groups of consumers whose electricity consumption is monitored. The data are then aggregated using a statistical model to provide overall national values as described in **Textbox 3.**

Time series for electricity generation and con-sumption in Denmark are shown in **Figure 6.** The consumption curve shows the realised consumption for the period 1990-2008, and consumption in the forecast period is temperature and calendar adjusted.

From 1990 to 2008, electricity consumption in Denmark increased by approx. 22%. Over the next three years, the development in electricity consumption will be characterised by the economic crisis, which started in earnest in the latter half of 2008. A return to economic development levels prior to the crisis is expected after 2012. Consequently, electricity consumption in 2009 is expected to be 5% lower than in 2008, and the classic electricity consumption level of 2008 will not return until 2013. From 2013 to 2020, an average annual increase of 1.2% in classic electricity consumption is expected. Overall, the electricity consumption forecast indicates an increase in electricity consumption of 6.4 TWh from 2008 to 2020. However, a part of the increase in electricity consumption can be attributed to a gradual implementation of heat pumps and electric vehicles. Consequently, the electricity consumption of heat pumps and electric vehicles constitutes 7% and 3%, respectively, of the total annual electricity consumption at 42.45 TWh in 2020.

Local generation in both Eastern and Western Denmark grew steadily in the period

Textbox 3

Electricity consumption developments in 2008

The growth rate of Danish electricity consumption is continuously monitored by electricity consumption panels, where electricity consumption is divided into the principal sectors: households, agriculture, industry, and trade and services.

Electricity consumption in 2008 fell by 1.9% compared to 2007 when the figure is adjusted for degree days, for example. In 2008, calendar and climate adjusted electricity consumption in the trade and services sector and the industrial sector fell by 1.2% and 3.3% respectively. The fall was especially due to the economic crisis, which severely impacted in the fourth quarter of 2008. This can be seen in the industry's output index, which rose by 0.5% in 2008, yet fell by 7% in the fourth quarter of 2008. Throughout 2008, household adjusted electricity consumption was falling, and variations during the year were modest. Overall, household electricity consumption fell by 1.9% in 2008. Agricultural electricity consumption rose by 0.4% in the same period.

The growth rates in the electricity consumption panels typically deviate from the actual changes in the recorded electricity consumption at system level. The deviation stems from statistical uncertainty on the panel.

from 1990 to 2000 in pace with the increasing number of local CHP plants. After some years of fairly constant generation from the local CHP plants, generation fell from 2005 to 2007 because many local CHP plants made the transition to selling their electricity generation on market terms. As shown in the status section, local generation has virtually remained unchanged from 2007 to 2008, although it is expected that natural gas-fired plants on market terms, similar to the coal-fired power stations, will increase generation in dry years. In the period 2009-2020, local generation is expected to be approx. 8 TWh annually.

Total wind power capacity has grown considerably since 1990. Thus, wind power accounted for approx. 19% of the Danish electricity consumption in 2008 against a mere 2% in 1990. In the forecast period, a significant expansion of Danish wind power capacity is assumed. Overall, installed wind turbine capacity will increase from 3,183 MW in 2008 to 5,626 MW in 2020. Wind power generation will increase from 7 TWh in 2008 to 15 TWh in 2020 as a result of the expansion plan.

Most of the wind turbine expansion in the forecast period is expected to be established offshore. In Eastern Denmark, the establishment of a new 200 MW offshore wind farm at Rødsand in 2010 and 600 MW at Kriegers Flak distributed as 300 MW in each of the years 2015 and 2016 are assumed. In Western Denmark, the commissioning of offshore wind farms totalling 1,000 MW is expected in the forecast period, consisting of 200 MW at Horns Rev 2 in 2009, 400 MW at Anholt in 2012 and a further two offshore wind farms of 200 MW each in 2019 and 2020. By the end of the forecast period, offshore wind turbines are expected to constitute 38% of the installed wind power capacity in Denmark, while generation from offshore wind turbines will represent almost half of all wind turbine generation because offshore wind turbines have substantially more full-load hours than land-based wind turbines.

It is assumed that the power link interconnecting the electricity grids on both sides of the Great Belt will be commissioned by 2010. The establishment of the Great Belt Power Link is primarily expected to result in electricity transmission from Western Denmark to Eastern Denmark. Thermal generation in Western Denmark is forecast to rise, and the increased generation will be consumed in Eastern Denmark or exported to Sweden.

Figure 6 Electricity consumption and electricity generation in Denmark.

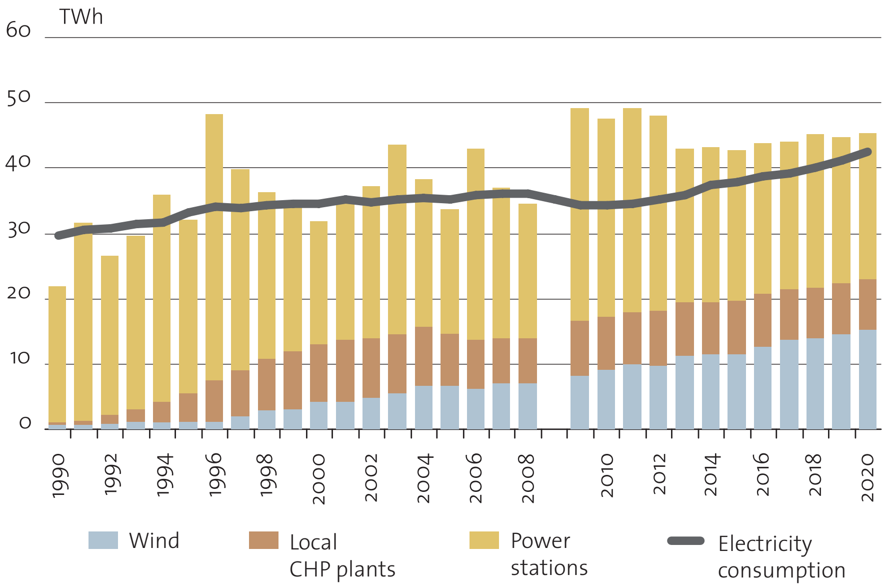


Figure 6 shows a substantial difference in generation from power stations in the years 2009-2012 and the remaining forecast years. The difference can be primarily attributed to the preconditions concerning the development in the CO_2 emission allowance price. For the years 2009-2012, the price of CO_2 emission allowances is based on the forward prices at Nord Pool, where the market expects a relatively low emission allowance price of approx. DKK 100 per tonne CO_2 as a result of the economic crisis. In the remaining years, the CO_2 emission allowance price is set at DKK 230 per tonne CO_2. Electricity prices used for the Nordic region and Germany in the calculation models are based on a fixed high emission allowance price for the entire forecast period. The CO_2 emission allowance price significantly affects the total generation costs of the power stations, and the fact that Danish power stations are more favourably positioned than foreign power stations in the simulations for the rest of the Kyoto period will lead to a substantial net generation surplus from 2009 to 2012. The implementation of heat pumps and electric vehicles means that a greater proportion of Danish wind power generation will be utilised domestically. This becomes evident when, for example, the development in **Figure 6** is compared with the forecasts of Environmental Report 2008, where a somewhat similar expansion of wind turbines was expected in Denmark. The conclusion of Environmental Report 2008 was that most of the new wind capacity would lead to increased net exports. Seen for the period 2013-2020, **Figure 6** shows falling net exports from 7 TWh in 2013 to 3 TWh in 2020. In the same period, a rise in wind generation of 3.9 TWh is expected as is a rise in electricity consumption of 6.5 TWh, of which the increased electricity consumption for heat pumps and electric vehicles constitutes 3.4 TWh.

At the same time, a fall in thermal electricity generation of 1.5 TWh can be seen in the period 2013-2020. However, it should be noted that the forecast calculations for Environmental Report 2009 assume an intelligent interaction between electric vehicles, heat pumps and the power system, so the new extensive electricity consumption occurs during those hours of the day when wind power generation is high and the electricity price is low. According to Energinet.dk's analysis, a lack of intelligent connections of heat pumps and electric vehicles to the power grid will lead to a need for additional capacity, equivalent to two power station units or two new interconnections for the import of electricity.

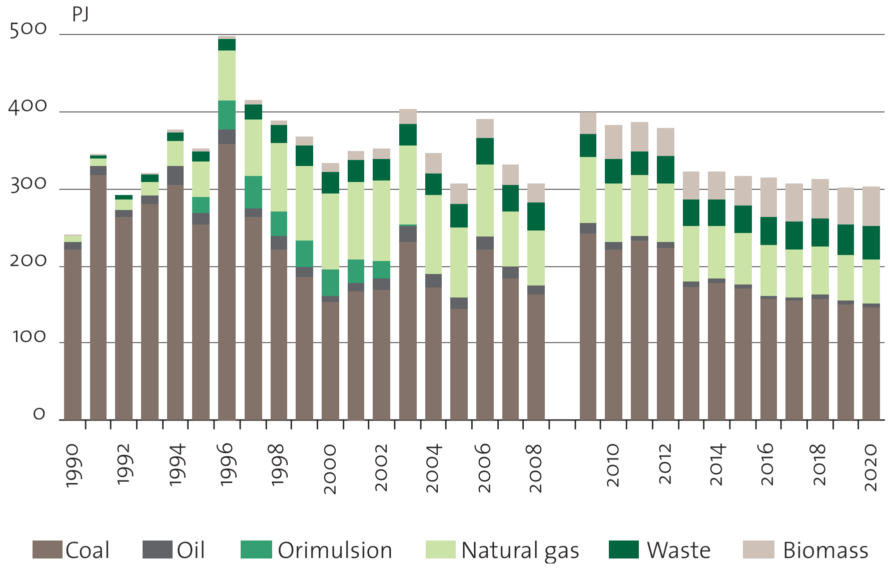
5.3 Fuel consumption

In **Figure 7**, the historical fuel consumption and fuel consumption in the forecast scenario are calculated on a national basis for the central and local CHP plants. Total Danish fuel consumption varies from one year to the next and depends on variations in imports and exports. The figures show that fuel consumption is highest in the years of high exports, eg 1996, 2003 and 2006.

In the period 1990-2008, the coal share of fuel consumption in the Danish electricity and CHP sector fell from 92% to 53%. This is primarily attributable to the increased share of natural gas following the expansion of natural gas-fired local CHP plants and the modification and adaptation of several of the large central power stations to natural gas and biomass. Furthermore, Orimulsion was used instead of coal at Asnæs Power Station Unit 5 in the period 1995-2003, but the unit has now reverted to coal as the main fuel. Even though, from a historical perspective, the coal share has been falling, the consumption of coal still varies greatly from one year to the next, as it is primarily the coal-fired plants that adjust their generation in relation to the current possibilities for electricity trading.

The historical period saw considerable growth in the use of biomass for electricity and CHP generation. In addition to a number of local CHP plants based on biofuels, biomass is currently utilised by Studstrup Power Station, Ensted Power Station, Amager Power Station, Avedøre Power Station, Herning Power Station and Randers CHP Plant. In the forecast period, it is assumed that the consumption of biofuels in Danish electricity and CHP generation will more than double - from 25 PJ in 2008 to 52 PJ in 2020. Unit 1 at Amager Power Station will be recommissioned at the end of 2009, after being modified to fire both coal and biomass. Moreover, the volume of biomass according to the Biomass Action Plan of

Figure 7 Fuel consumption in Denmark.



1993 is expected to be fully utilised when the new straw-fired unit at Fyn Power Station is commissioned in the course of 2009.

As a part of the political agreement of 21 February 2008, an opportunity arose for DONG Energy to use coal at Avedøre Power Station Unit 2 and at Skærbæk Power Station. The change is conditioned by the increased use of biomass at other plants. Consequently, the establishment of supplementary coal-firing at Avedøre Power Station Unit 2 in 2010 and simultaneous renovation with supplementary biomass firing at Avedøre Power Station Unit 1 are assumed. In the forecast period, a renovation for supplementary biomass firing is further assumed at Asnæs Power Station Unit 5 in 2015 as well as increased biomass capacity at Ensted Power Station in 2015 and at Studstrup Power Station Unit 4 in 2019.

Although the overall consumption of biofuels increases in the forecast period 2009-2020, some years of falling biomass consumption will occur due to a renovation or scrapping of existing biomass-fired power station units. In particular, a fall in the use of biomass occurs in 2011 due to an expected scrapping of Amager Power Station Unit 2 and renovation of Avedøre Power Station Unit 2. Correspondingly, biomass consumption is reduced in 2019, compared with the previous year, due to the scrapping of Studstrup Power Station Unit 3.

The use of waste for electricity generation has also increased in the period 1990-2008, as many waste incineration plants, which formerly only generated district heating, have now been converted to CHP generation. Thus, the increase not only reflects a rise in the volumes of incinerated waste, but also shows that the incineration of waste is now used for electricity generation. In the forecast period, the consumption of waste for the generation of electricity and CHP is expected to increase by approx. 20%, compared with 2008. The increase in waste consumption is mainly expected to occur through an expansion of the capacity at existing waste incineration plants.

Figure 7 shows a fall in the consumption of the fossil fuels: coal, natural gas and oil in the period 2013-2020. The fall can be partly explained by an increase in biomass consumption at the large power plants and partly by a displacement of thermal generation based on fossil fuels in connection with the implementation of heat pumps in the district heating sector. According to the forecast, the share of fuel consumption for the generation of electricity and CHP in Denmark represented by biomass and waste will increase from 12% in 2013 to 31% in 2020.

5.4 Development of key figures 2020

In December 2008, the EU adopted a new climate and energy package, which establishes binding national targets for the share of renewable energy in total energy consumption. The share of renewable energy sources of the EU's total energy consumption should be at least 20% in 2020. In the case of Denmark, the target is set at 30%, compared to 17% in 2005. A national action plan describing how RE targets will be achieved must be prepared by each member state by 30 June 2010. Amongst these, specific targets must be established for the share of renewable energy within the electricity, heat, cooling and transport sectors in 2020.

The specific target for the share of renewable energy of the electricity supply in Denmark is as yet not set, but it is expected that a great proportion of the Danish target should be achieved through the expansion of renewable energy in the electricity sector. In the forecast period, a significant expansion in renewable energy is also assumed, especially wind power and biomass. In 2008, the RE share of electricity consumption in Denmark was around 28%, of which wind power alone constituted 19%. In 2020, wind power is expected to cover 36% of Danish electricity consumption, while the RE share will increase to 53% according to the forecast. Overall, wind power accounts for around two-thirds of the RE share in the electricity sector in both 2008 and 2020.

The combination of an increasing share of renewable energy in the electricity sector and a significant expansion in the use of heat pumps and electric vehicles will thus contribute to an increased share of RE in the heating and transport sectors. Energinet.dk's analysis explored more closely how the electricity sector and specific intelligent electricity consumption in the form of electric vehicles and heat pumps could contribute to the observance of Denmark's RE target in 2020, see **Textbox 4.**

Textbox 4

The significance of heat pumps and electric vehicles for the 2020 targets

In March 2009, Energinet.dk published the results of the analysis 'Efficient use of wind-power based electricity in Denmark - interaction between wind power, heat pumps and electric vehicles'.

The overall objective of the report was to analyse the significance of implementing heat pumps and electric vehicles during extensive expansion of wind power. The analysis shows that heat pumps and electric vehicles have huge potential to create large new flexible electricity consumption, which means that a greater share of Danish wind power generation can be utilised domestically. However, this requires the development of solutions for an intelligent interaction between electric vehicles, heat pumps and the power system.

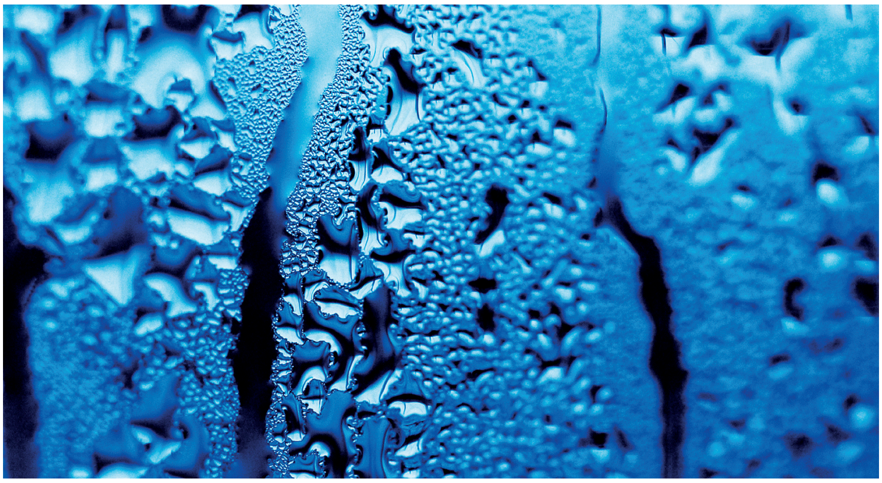
The report also shows that heat pumps and electric vehicles can become a key factor in the fulfilment of Denmark's 2020 targets. The RE share of the total energy consumption should increase from 17% in 2005 to 30% in 2020. Of this, heat pumps and electric vehicles are expected to contribute approx. 5 percentage points. In the sector not covered by the emissions trading scheme, Denmark has to reduce CO_2 emissions by approx. 7.5 million tonnes in 2020 compared with 2005. In that case, individual heat pumps and electric vehicles could contribute approx. 3 million tonnes.

5.5 Emissions to the air 1990-2020

The firing of fossil fuels (coal, natural gas and oil) and biofuels (straw, wood chips, wood waste, etc.) results in emissions to the air of greenhouse gases and acidifying gases as well as a number of other substances. Emissions are discharged through stacks with varying degrees of flue gas treatment.

5.5.1 Greenhouse gases

CO_2, CH_4 and N_2O are the three greenhouse gases emitted in connection with combustion. Furthermore, the greenhouse gas SF_6 is emitted from the transmission system. CH_4, N_2O and SF_6 are stronger greenhouse gases than CO_2, and they are converted into a CO_2 equivalent emission by multiplying emission (in weight) with the equivalency factors 21 for CH_4, 310 for N_2O and 23,900 for SF_6.



Carbon dioxide – CO_2

Total CO_2 emissions from the Danish electricity and CHP sector appear in **Figure 8**. The figure also shows a curve for CO_2 emissions adjusted for variations in imports and exports. The curve therefore depicts general developments in the sector.

CO_2 emissions follow the development of fuel consumption at the power stations and therefore vary substantially from year to year, depending on electricity trading with neighbouring countries. Adjusting for imports and exports gives an overall emissions reduction of 24% in the 1990-2008 period. The main reason for this is a conversion of Danish electricity and heat generation to less CO_2 intensive fuels such as natural gas as well as an increased use of renewable energy sources.

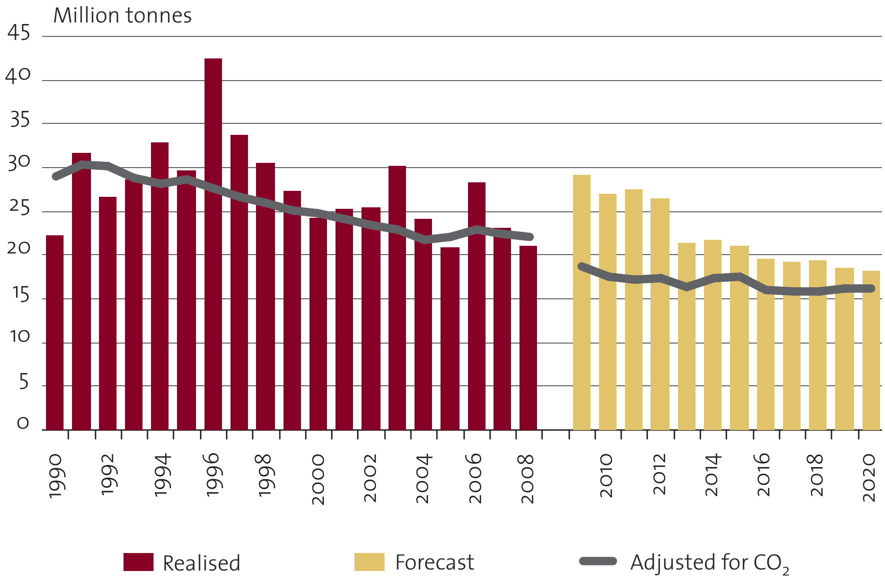
However, in connection with the Climate Convention, including the reduction targets set out in the Kyoto Protocol, CO_2 emissions cannot be adjusted for cross-border electricity trading. In this context, the actual emissions bars apply. However, the majority of CO_2 emissions from Danish electricity and CHP generation are covered by the EU emissions trading scheme. If an individual enterprise participating in the emissions trading scheme emits more CO_2 than its allocated free allowances, the enterprise will be required to take steps to buy allowances or credits in the market to cover its actual CO_2 emissions. The development of realised CO_2 emissions therefore shows to what extent electricity and CHP generators contribute to ensuring that Denmark fulfils its climate obligations through domestic initiatives.

The actual CO_2 emissions from electricity and CHP generation in the forecast period follow the development of thermal generation as described in the previous sections. Focus on the development in the third phase of the EU's emissions trading scheme from 2013 to 2020 shows a fall in CO_2 emissions of approx. 3 million tonnes. The fall can be partly explained by a drop in thermal generation and partly by a rise in the RE share of thermal generation. Since neither the expansion of renewable energy sources nor the fall in thermal generation occurs steadily in the period, a steady fall

Table 8 Relative distribution of greenhouse gases from electricity and CHP generation in 2008 and 2020.

Distribution of greenhouse gases 2008 and 2020	1,000 tonnes of CO_2 equivalents Realised 2008		Forecast 2020	
CO_2 (carbon dioxide)	21,011	98%	17,378	98%
CH_4 (methane)	250	1%	302	2%
N_2O (dinitrogen oxide)	109	0.5%	102	0.6%
SF_6 (sulphur hexafluoride)	9	0.04%	9	0.05%
Total greenhouse gases (CO_2 equivalents)	21,378	100%	17,791	100%

Figure 8 CO_2 emissions from electricity and CHP generation in Denmark.



in CO_2 emissions is not seen either. This relationship is especially evident in the variation of the adjusted CO_2 emission in the forecast period.

The EU's climate and energy package sets an overall target for the reduction of greenhouse gas emissions in the EU by 20% in 2020 in relation to 1990. This reduction obligation is distributed between the sectors subject to allowances and sectors not subject to allowances. In 2020, the enterprises subject to emission allowances must have reduced their total emissions by 21% in relation to 2005. This is achieved by reducing the number of emission allowances in the European emission allowances system linearly until 2020 by 1.74% per year. Greenhouse gas emissions in the sectors not subject to emission allowances must be reduced by 10% in relation to 2005. This is achieved by setting individual targets for each member country. Denmark's individual target for reductions is set at 20%. If a consensus is reached on an international climate agreement in 2009, the EU is prepared to raise the level for the reduction of greenhouse gases to 30%. Under such circumstances, the increased commitment will be distributed proportionally to the enterprises covered by the emission allowances scheme and the national targets.

Through the assumed expansion of heat pumps and electric vehicles, electricity will be more widely used to replace fossil fuels in the heating and transport sectors and thus contribute to reducing CO_2 emissions in the sectors outside the emission allowances scheme. As shown in the results of Energinet.dk's analysis in **Textbox 4**, the implementation of heat pumps and electric vehicles can contribute significantly to the fulfilment of Denmark's climate commitments in 2020. The analysis can be read in its entirety at www.energinet.dk.

Other greenhouse gases

Emissions of greenhouse gases from electricity and CHP generation are dominated by the greenhouse gas CO_2. The greenhouse gases CH_4, N_2O and SF_6 only contribute marginally to emissions. The relative distribution of greenhouse gases converted to CO_2 equivalents can be seen in **Table 8.** Emissions of SF_6 are not included in the forecast models used. It is therefore assumed that emissions of this substance will remain constant at the 2008 level.

5.5.2 Acidifying gases

In the atmosphere, acidifying gases such as SO_2 and NO_x form chemical compounds with the water vapour in the air and turn into acids, which then harmfully impact natural areas and buildings in the form of acid rain.

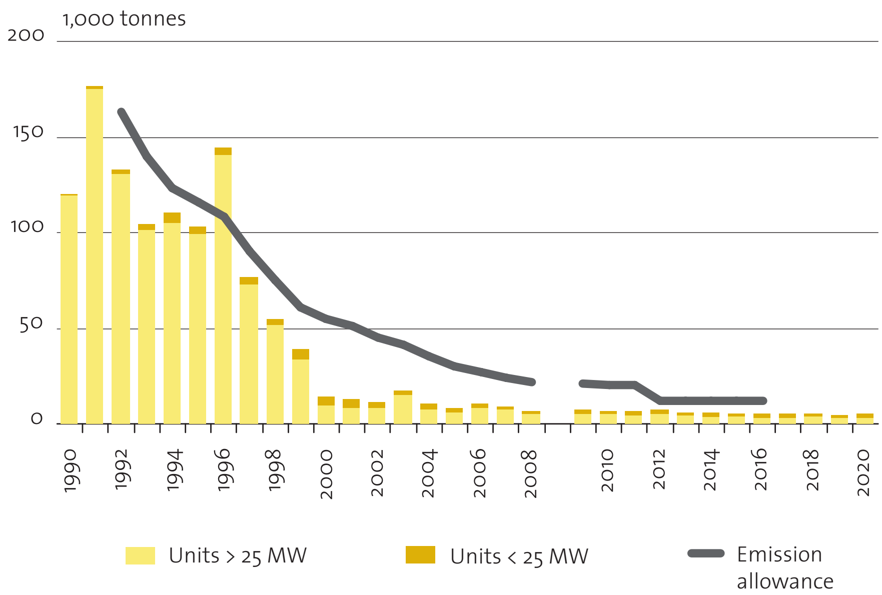
In accordance with the Gothenburg Protocol and the National Emission Ceilings Directive (NEC), Denmark is obliged to limit its annual emissions of SO_2, NO_x, VOC and NH3 to 55,000 tonnes, 127,000 tonnes, 85,000 tonnes and 69,000 tonnes respectively. The emission ceilings must be reached as from 2010. It is also expected that the EU Commission will lower the emission ceilings for these four substances, which will be applicable from 2020.

The emission of acidifying gases in the electricity sector is regulated by means of emission threshold values for the individual plants. Since 1 January 2000, the electricity sector has also been subject to a sulphur tax. Moreover, the Danish executive order on SO_2 and NO_x emission allowances sets an upper limit for the volumes of SO_2 and NO_x, emissions permitted annually from plants larger than 25 $MW_{electricity}$. Each year, the Danish Energy Agency determines the allowances for the coming four-year period including provisional allowances for a further four years. The SO_2 emission allowance applies to actual emissions, while the NO_x emission allowance concerns emissions adjusted for exchange.

With effect from 1 January 2010, a tax will be introduced for NO_x emissions of DKK 5 per kg of gas emitted to the atmosphere upon combustion. In the period 2010-2015, the tax on NO_x emission increases annually by DKK 0.1 per kg NO_x, so that as of January 2015, the tax will constitute DKK 5.5 per kg NO_x. The implementation of the NO_x tax will lead to a repeal of the executive order on SO_2 and NO_x emission allowances. This repeal is as yet not evident in the forecast figures (**Figure 9** and **Figure 11**), as the emission allowances are specified for the entire forthcoming eight-year period.

By the end of 2007, all generating facilities with a thermal output of 50 MW and above must observe the minimum requirements for emissions of SO_2 and NO_x set out in the Danish executive order on large combustion plants. In practice, plant owners can either choose to scrap the plants, declare limited operations until 2016 without reducing emissions, or renovate the plants and establish environmental facilities. Fyn Power Station Unit 3 is the only unit that has declared limited operations. Stigsnæs Power Station Unit 1 and Asnæs Power Station Unit 4 were taken out of normal operation because they could not meet the stricter emission requirements. Similarly, Asnæs Power Station Unit 2 is expected to be decommissioned before 1 January 2016, when the NO_x emission requirements in the executive order will be tightened even further.

Figure 9 SO_2 emissions from electricity and CHP generation in Denmark.



Sulphur dioxide - SO_2

Actual and expected SO_2 emissions from electricity and CHP generation in Denmark as a whole can be seen in **Figure 9**.

Actual SO_2 emissions fell by approx. 94% from 1990 to 2008. The fall in SO_2 emissions since 1990 is attributable to a reduction in the use of coal, increased use of natural gas, the commissioning of desulphurisation units at the central power stations and waste-fired plants as well as the use of fuel with lower sulphur content. After 1999, the fall is primarily attributable to a higher removal rate at desulphurisation units and a fall in generation at units without desulphurisation facilities due to the sulphur tax, which was introduced in 2000.

Higher market prices in dry years have historically led to substantial increases in SO_2 emissions as a consequence of increased generation at units with no desulphurisation facilities. Most of the major power stations in Denmark are equipped with desulphurisation units today. Stricter emission requirements in the executive order on large combustion plants contribute to a narrowing of the gap between SO_2 emission volumes in years of high and low precipitation.

After the implementation of the sulphur tax in 2000, the executive order on emission allowances has not had any practical importance for the regulation of SO_2 emissions from plants subject to emission allowances. In fact, SO_2 emissions are significantly below the emission allowance in the forecast period. With expected emissions in 2010 of approx. 7,000 tonnes, the electricity sector thus contributed significantly to ensuring that Denmark will be able to fulfil its international obligations (the NEC Directive and the Gothenburg Protocol), ie maximum SO_2 emissions of 55,000 tonnes by 2010.

Nitrogen oxides – NO_x

Actual and expected NO_x emissions from electricity and CHP generation in Denmark as a whole can be seen in **Figure 10.**

Actual NO_x emissions fell by approx. 70% nationally in the period from 1990 to 2008. Western Denmark accounted for the sharpest reduction at 71% compared to the level in 1990, while Eastern Denmark reported a reduction of 67%.

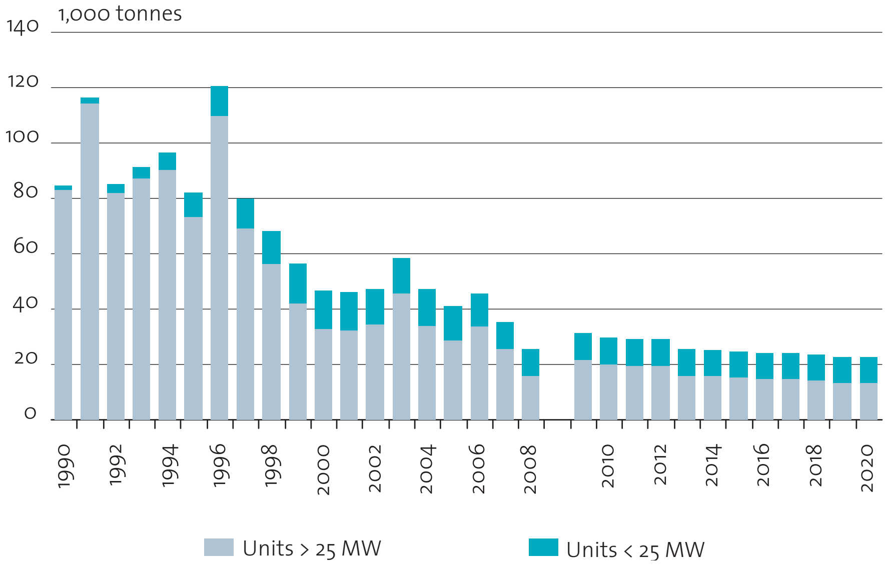
The fall in NO_x emissions since 1990 is primarily attributable to the introduction of NO_x reducing measures (low-NO_x burners and deNO_x units) at central power stations. Fuel conversions only contribute to a limited extent towards reducing NO_x as considerable volumes of NO_x are emitted from biomass-fired plants and other sources.

Under the NEC Directive and the Gothenburg Protocol, Denmark is committed to reducing its NO_x emissions of to 127,000 tonnes by 2010. Historically, the electricity sector has accounted for approx. 30% of total NO_x emissions in Denmark. According to the forecast, overall electricity and CHP generation will contribute approx. 30,000 tonnes of NO_x in 2010.

The Danish executive order on emission allowances permits the adjustment of NO_x emissions for international exchange. NO_x emissions adjusted for exchange in the period 1990-2020 can be seen in **Figure 11.**

From 2003 to 2007, the executive order on emission allowances imposed great demands on the power generators covered by the emissions trading scheme to limit their

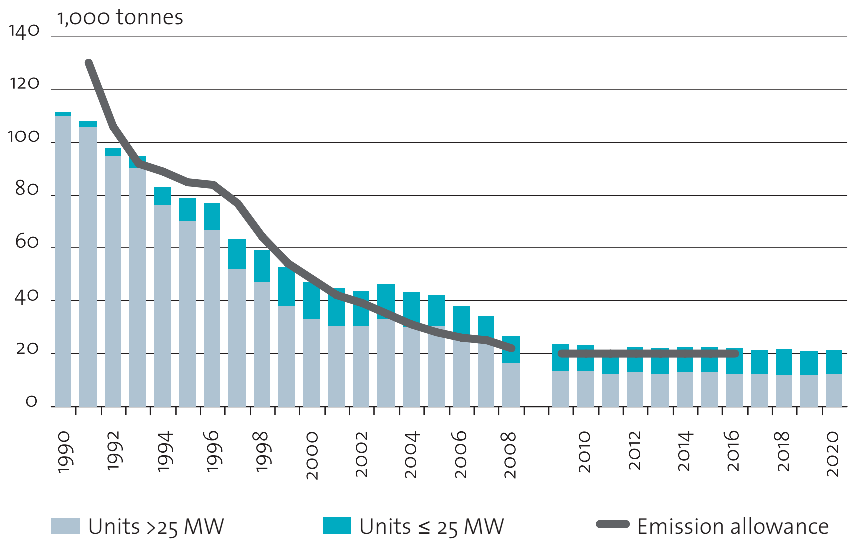
Figure 10 Actual NO_x emissions from electricity and CHP generation in Denmark.



NO_x emissions. In particular, several plant owners have been forced to reduce their emissions more than had been required in respect of their environmental approval. As detailed in the status section, NO_x emissions adjusted for exchange from facilities larger than 25 $MW_{electricity}$ would be well below the permitted allowance as of 2008. In the forecast period, the NO_x emission allowance is thus expected to be observed by a margin in excess of 6,000 tonnes.

Small local CHP plants not subject to the NO_x allowance contribute significantly to NO_x emissions. Towards the end of the forecast period, they represent 42% of NO_x emissions adjusted for exchange. The same plants are expected to account for 40% of the actual emissions in 2020, see **Figure 11.** The NO_x tax with effect from 2010 will apply to all plants. Consequently, the tax will also provide an added incentive for the small plants to reduce NO_x emissions.

Figur 11 NO_x emissions from electricity and CHP generation in Denmark, adjusted for exchange.



6. Electricity transmission grid

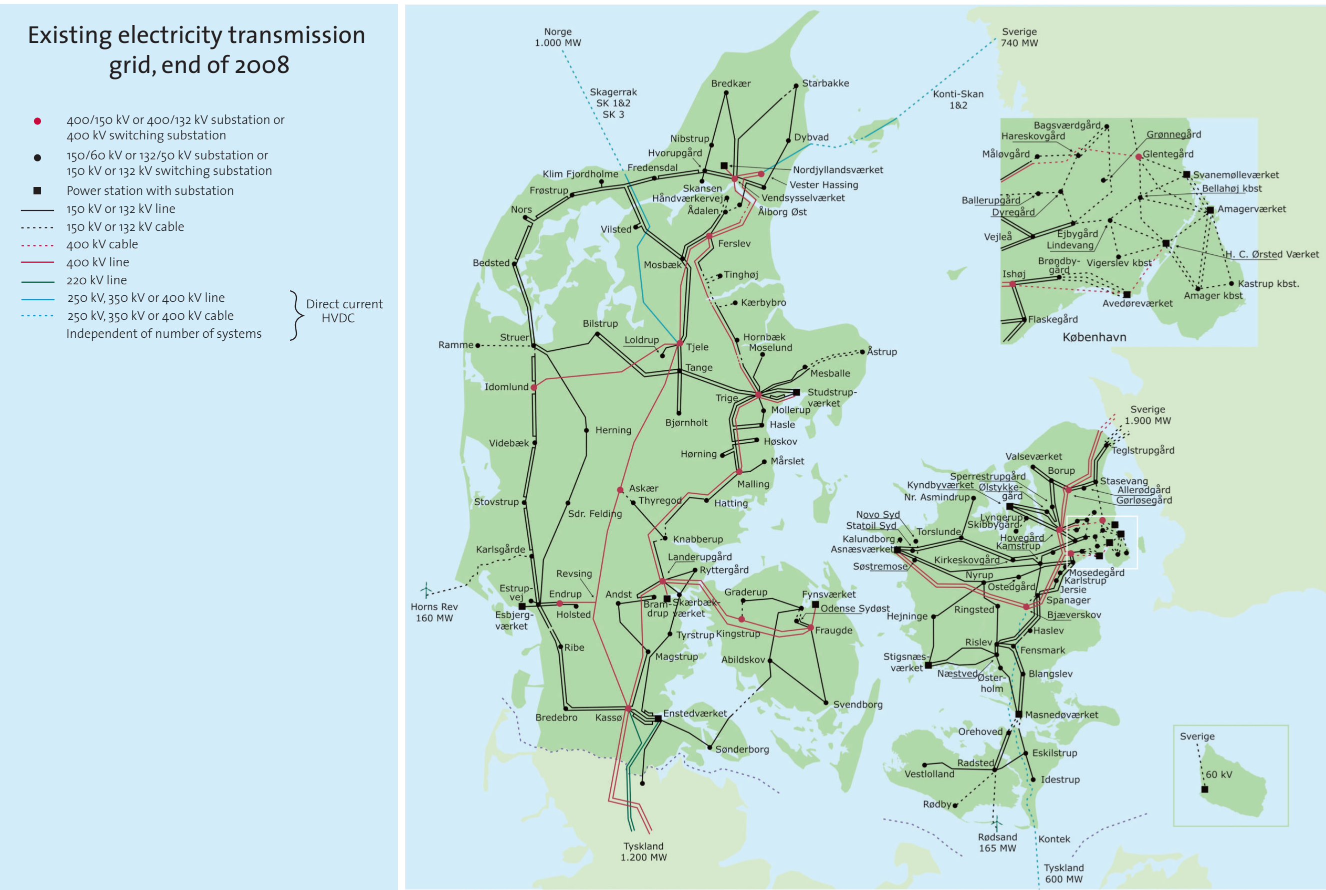
Energinet.dk owns and operates the main transmission grids for electricity and natural gas and is responsible for the security of electricity and gas supply. This chapter describes the operation of the electricity transmission grid and related environmental impacts, while chapter 7 describes the environmental impacts of transmitting natural gas.

6.1. Electricity transmission grid structure

Energinet.dk owns the 400 kV facilities, including three HVDC stations (which convert direct current into alternating current and vice versa) and the interconnections. In 2008, Energinet.dk also acquired DONG Energy's regional 132 kV transmission grid in North Zealand. The remaining 150/132 kV grids are owned by the regional transmission companies, which place them at the disposal of Energinet.dk. **Table 9** shows the constituent elements of the electricity transmission grid in 2008.

The high-voltage transmission system in Denmark, which is currently separated into a Western and an Eastern transmission system, is illustrated on the map in **Figure 12.** The grid in Western Denmark is connected to the European UCTE grid,

Figure 12 Electricity transmission grid in Denmark, end of 2008.



whereas Eastern Denmark is connected to the Nordic Nordel grid. As the two grids are not synchronised, the coming Great Belt Power Link (which is expected to be commissioned in autumn 2010) must be constructed as an HVDC connection.

The environmental impact from the transmission of electricity primarily results from losses in the high-voltage grid. In addition, the transmission grid gives rise to a number of other environmental impacts, for instance the use of chemicals used in operation (eg SF_6 gas).

6.2 Transmission and distribution losses

The most significant environmental impact of the transmission of electricity is transmission and distribution losses. Losses occur because of the resistance in the individual components of the system. Resistance leads to losses because the electrical energy converts to heat, which is then lost to the ambient environment. For each kWh supplied to the consumer, a kWh plus a sufficient volume to cover the loss from transmission in the system must be generated.

Such losses can be reduced by restructuring and upgrading the grid/network. Losses are unavoidable, but all electricity grid operators seek to reduce them. Transmission losses in Eastern and Western Denmark in 2008 can be seen in **Table 10.**

Developments in transmission and distribution losses for the 1995-2008 period can be seen in Figure 13. During that period distribution losses amounted to approx. 5% while transmission losses constituted about 1-2% in both Eastern and Western Denmark. Distribution losses have been estimated at 5% for the 2008 calendar year. The precise figures will be collected in the course of 2009 from the local grid companies and consequently disclosed in next year's environmental report.

Transmission and distribution losses have been influenced by several factors. In the main high-voltage grid - comprising the 400 kV, 220 kV, 150 kV and 132 kV grids - transmission losses are influenced by exchange with neighbouring countries. High levels of exchange and transit result in substantial losses including in the HVDC connections. Energinet.dk seeks to minimise losses by optimising its operating strategy.

In the distribution network, which involves the lower voltage levels of 60 kV and 50 kV down to 0.4 kV, losses are determined by the transactions of the local grid companies. Local electricity generation with low-voltage supplies and shorter distances between power generators and consumers contribute to reducing distribution losses.

Table 9 Elements of the electricity transmission grid for Eastern and Western Denmark in 2008.

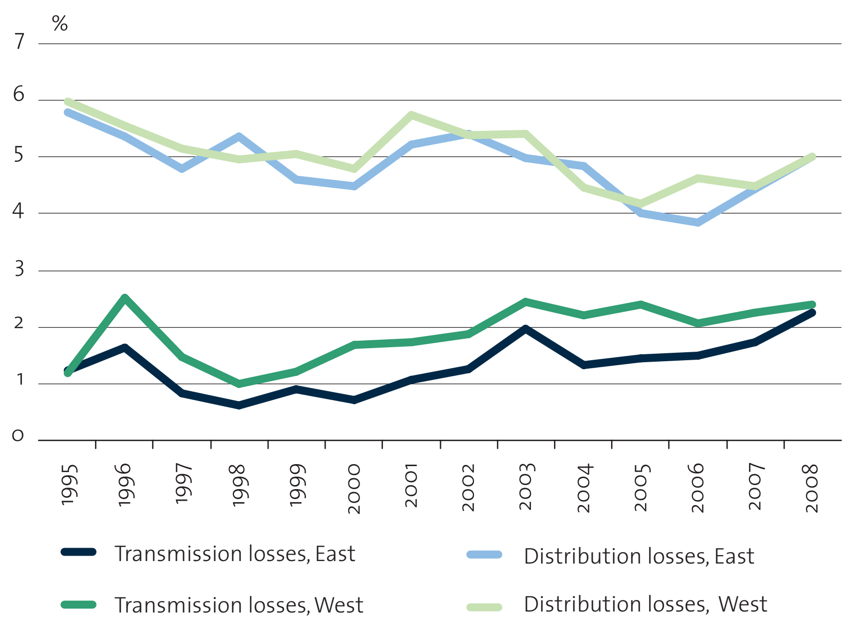
Electricity transmission grid in 2008		**Overhead lines Track km**	**Cables Track km**	**Substations Number**	**HVDC Number**
Eastern Denmark	132 kV	886	400	68	-
	400 kV	144	51	8	1
Western Denmark	150 kV	1,385	264	74	-
	220-400 kV	873	28	18	2

Table 10 Transmission losses in the two TSO areas, 2008.

Transmission losses, GWh (400 – 150/132 kV)	**Eastern Denmark** 2007	**2008**	**Western Denmark** 2007	**2008**
Transmission grid	198	**272**	276	**291**
HVDC connections	54	**55**	211	**226**
Total transmission losses	252	**328**	487	**517**

Note: Total transmission losses in Eastern Denmark do not tally with the transmission losses, which have been calculated at 359 GWh in Tables 1 and 6. This is due to the national calculation being from January 2009, whereas the figure in Table 10 has subsequently been adjusted for deviations.

Figure 13 Development in transmission and distribution losses in the period 1995-2008.



One way of reducing losses is to restructure the grid/network so that it is upgraded from lower voltage levels to higher ones, eg from 150 kV to 400 kV or from 10 kV to 60 kV.

For the most important emission parameters, Energinet.dk has calculated the label for the electricity fed to the grid in Eastern and Western Denmark respectively. The label for the two areas basically corresponds to a declaration ex plant, with net electricity imports being considered as a virtual power station that also generates electricity for the grid.

The ex plant labels and the stated transmission losses are used to calculate the emissions and the consequent environmental impacts that the transmission losses caused in 2008. This can be seen in **Table 11.**

6.3 Use and emissions of SF_6 gas

The Kyoto Protocol concerns the limitation of emissions of greenhouse gases. The principal greenhouse gas is CO_2. Another very aggressive greenhouse gas, sulphur hexafluoride (SF_6), which is used for operating and maintaining the transmission grid, is also included in the Kyoto accounts. As emissions of SF_6 are very low, historically emissions have only accounted for about 1‰ of total Danish emissions of greenhouse gases calculated as CO_2 equivalents.

Energinet.dk and the regional transmission companies use SF_6 gas in high-voltage components over 100 kV. In addition, the gas is used as an insulation medium in indoor substations called GIS units. The import or use of SF_6 gas in new products is not permitted, but as no gases with properties similar to those of SF_6 gas are known as potential substitutes, high-voltage components over 1 kV are exempt from this rule.

The use of SF_6 gas in the transmission grid in 2008 can be seen in **Table 12.** Total emissions of SF_6 gas were 355 kg, corresponding to 8,502 tonnes of CO_2 equivalents. The figures are based partly on Energinet.dk's own use, and partly on reports from the regional grid companies in Eastern and Western Denmark. Reports are submitted by all regional grid companies, ie from the entire transmission grid in Denmark. This is the second year that reports have been submitted from all the regional companies; values for 2008 and last year's environmental report cannot therefore be immediately compared with values from years prior to 2007. These complete statements will presumably provide a more accurate representation of the use of SF_6 gas in Denmark.

In the coming years, the use of SF_6 gas is set to rise in the wake of more offshore wind farms coupled with increased undergrounding of the high-voltage grid and insulation of units in urban areas. Consequently, stocks of SF_6 gas have risen, as for example transformers and cabling to a new offshore wind farm at Horns Rev will be commissioned in 2009.

Energinet.dk is very mindful of the fact that the increased use of SF_6 gas presents a potential risk for the emission of a very potent greenhouse gas. Consequently, every endeavour is made to constantly improve the security of work routines when handling SF_6 gas.

Table 11 Environmental impacts of transmission losses in Denmark in 2008.

Environmental impacts of transmission losses in 2008	Label Eastern Denmark g/kWh	Label Western Denmark g/kWh	Environmental impacts of losses tonnes
Total greenhouse gases (CO_2 equivalents)	423	446	382,946
NO_X (nitrogen oxides)	0.45	0.46	401
SO_2 (sulphur dioxide)	0.17	0.09	106
Residual products	33	34	29,838
Fuel consumption	**MJ/kWh**	**MJ/kWh**	**TJ**
Consumption of non-renewable energy sources	5.7	5.2	4,714
Consumption of renewable energy sources	1.6	1.5	1,387

Table 12 Use and emissions of SF_6 gas in Denmark in 2008

Use and emissions of SF_6 gas in Denmark in 2008.	Eastern Denmark kg	Western Denmark kg
Use in high-voltage installations > 100 kV		
New SF_6 gas in depot for later use	546	1,815
SF_6 gas in use	30,726	8,813
Burnt SF_6 gas in depot	240	13
Emissions in high-voltage installations > 100 kV		
SF_6 gas refilled into components in operation	262	81
SF_6 gas emitted in connection with breakdowns/major faults	0	10
SF_6 gas emitted during overhaul	<1	1
SF_6 gas emitted in connection with control and measuring	0	1
Total SF_6 gas emitted	262	93
SF_6 gas emitted as CO_2 equivalents	**6,271,360**	**2,231,065**

7. Natural gas transmission grid

Energinet.dk owns and operates the Danish natural gas transmission grid, which is connected to the neighbouring transmission grids in Sweden and Germany. Natural gas is produced in the Danish section of the North Sea and transmitted in pipelines to the gas treatment plant in Nybro near Varde. From Nybro, Energinet.dk takes over the transmission of natural gas to the Danish distribution grids, where the regional natural gas companies receive the gas for further distribution.

Energinet.dk is also responsible for natural gas transits to Germany and Sweden. Moreover, natural gas is transmitted from Germany to Denmark in connection with cross-border trading of the gas. Total natural gas trading has to date always resulted in net exports and thus physical transmission to Germany.

Two Danish natural gas storage facilities are connected to the natural gas transmission grid. One of the facilities, Lille Torup natural gas storage facility in Jutland, is owned by Energinet.dk. The other facility, located in Stenlille on Zealand, is owned by DONG Energy. As TSO, Energinet.dk is entitled to purchase storage capacity in both natural gas storage facilities. Energinet.dk Gaslager A/S is considering an expansion of the storage capacity at Lille Torup natural gas storage facility to allow for the sale of more storage capacity to Danish and foreign customers. The project is described in section 7.5.

The supply of gas from the Danish section of the North Sea is expected to decline after 2010. In its proposal for a long-term energy policy of 19 January 2007, the Danish government therefore emphasised the necessity of expanding the gas infrastructure to link the Danish natural gas system with neighbouring areas that provide access to new natural gas resources. Energinet.dk is party to the Skanled Project, whereby natural gas from the Norwegian section of the North Sea can be piped into the Danish system at Frederikshavn via a

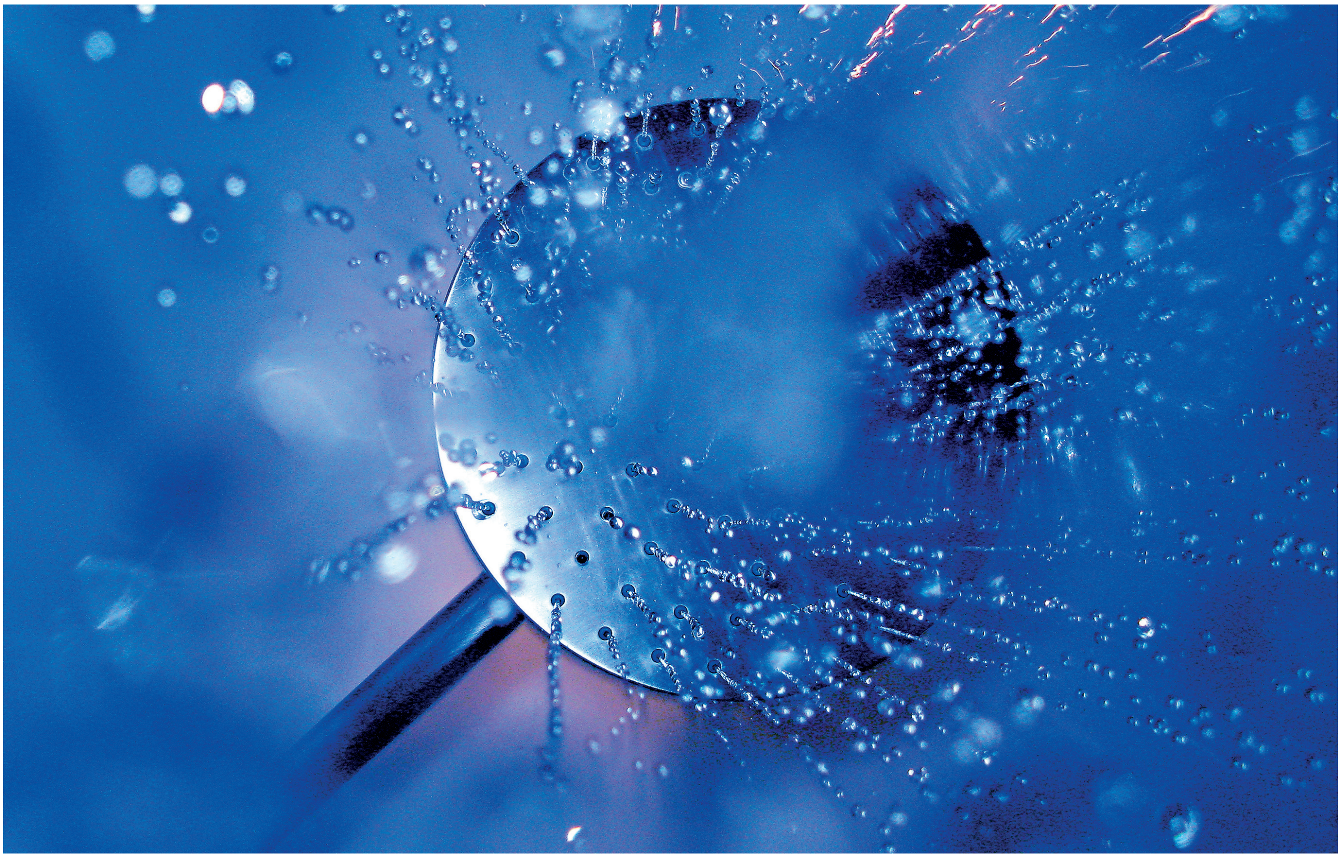
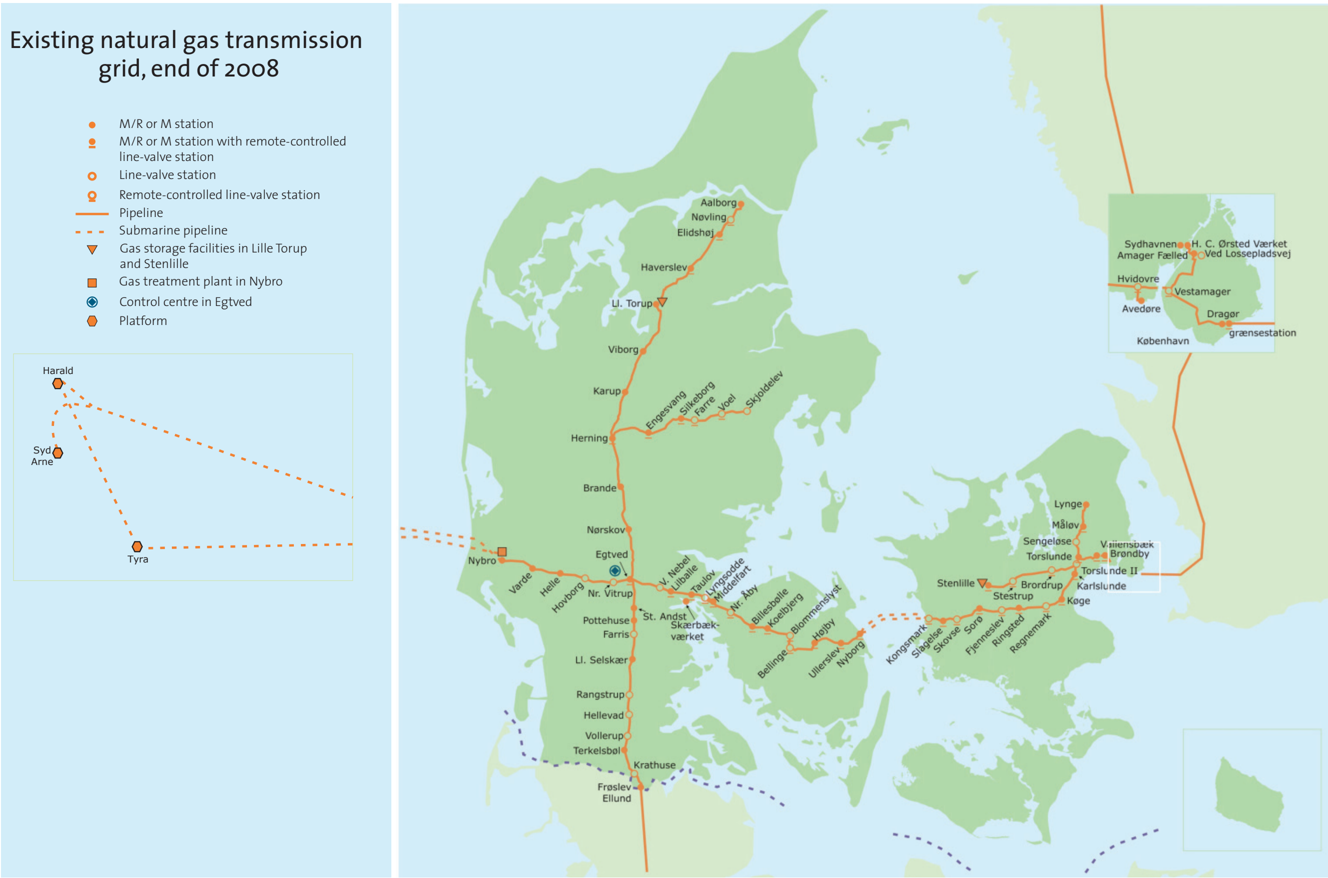


Figure 14 Natural gas transmission grid in Denmark, end of 2008.



Danish connection to the pipeline, which runs from Norway to Gothenburg in Sweden.

This chapter deals with the operation of the natural gas transmission grid and the operation of Lille Torup natural gas storage facility and the ensuing environmental impacts. This chapter only focuses on the environmental impacts of transmitting natural gas in the part of the transmission grid that is owned by Energinet.dk. For the environmental impacts of transport through the distribution grid, refer to reports and statements prepared by the regional natural gas companies. The environmental impacts of using natural gas in electricity and CHP generation are described in other chapters of Environmental Report 2009.

This chapter does not include the environmental impacts of producing and transmitting natural gas from the North Sea to the gas treatment plant in Nybro. In the background report to Environmental Report 2009, a more detailed analysis of the route natural gas takes from the North Sea to its end use in Denmark is presented.

7.1 Natural gas grid structure

The natural gas transmission system in Denmark consists of the gas pipelines in the Danish section of the North Sea, the north-south and east-west transmission lines, the grid of distribution lines to consumers as well as two underground natural gas storage facilities and a gas treatment plant. Meter and regulator (M/R) stations are established along the gas transmission lines. At M/R stations, the gas flow through the station is metered, and the gas pressure is reduced from 80 bar to the pressure in the distribution grid (40 or 19 bar). The natural gas is heated by this pressure reduction to avoid condensation in the distribution lines. The M/R stations are unmanned, but they are monitored from Energinet.dk's control centre in Egtved. The distribution companies are responsible for the transport to customers. Natural gas is consumed by private households, commercial enterprises, industries, CHP plants, etc. that are connected to the local distribution grids. Three of the large power stations are connected directly to the natural gas transmission grid.

Overall, Energinet.dk's natural gas transmission grid consists of 860 km of pipelines, 42 M/R stations and four meter stations as well as Lille Torup natural gas storage facility.

Figure 14 illustrates the Danish natural gas transmission system.

7.2 Environmental impacts of natural gas transmission

Energinet.dk is committed to ensuring a high level of security of supply, as few accidents as possible and the least possible environmental impact from the transmission of natural gas in Denmark. The most significant environmental impacts from the transmission of natural gas are as follows:

- Direct discharge into the atmosphere. When a gas pipe is inspected for corrosion and deformations, electronic metering equipment is sent into the pipeline. In this process, natural gas from the trap is discharged directly into the atmosphere.
- Consumption of natural gas for heating at M/R stations. Natural gas is used for heating the natural gas at the M/R stations before it is led into the distribution lines at a lower pressure. The heating process entails the atmospheric emission of primarily CO_2, which is a greenhouse gas.
- Statutory addition of odorant. The odorant contains sulphur and when burned together with the natural gas, it emits sulphur dioxide, which contributes to acid rain.

Energinet.dk constantly endeavours to reduce environmental impacts through technological innovation. Such endeavours include the ongoing work to implement environmental and energy improvements at the M/R stations.

In 2008, Energinet.dk received and transmitted 7.6 billion Nm^3 of natural gas in the main transmission grid. Compared with 2007, transmission increased in 2008.

Table 13 Environmental impacts from natural gas transmission in Denmark in 2008.

Environmental impacts from natural gas transmission in 2008		
Total natural gas transmission	billion Nm^3	7.6
Emissions of natural gas	Nm^3	24,204
Emissions of natural gas in per thousand of transmission	‰	0.004
Emitted volumes of CO_2 equivalents	tonnes	344

Overall, the Danish consumption of natural gas remained unchanged in 2008, compared to 2007. The increase in the volume of transmitted natural gas was exported to Germany. In addition, the volume of natural gas, which is exported directly to the Netherlands from the North Sea fell, which led to an increase in the share of North Sea production that is sent to Denmark.

Natural gas transmission gives rise to minor atmospheric emissions of natural gas, primarily for safety reasons. Such emissions, also known as discharge gas, occur in connection with maintenance work, repairs and gas pipe metering and when special metering equipment is sent through the transmission grid.

Environmental impacts from the emission of natural gas in 2008 are shown in **Table 13.** Natural gas consists primarily of methane (CH_4), a greenhouse gas that can be converted into CO_2 equivalents using a factor of 21. In 2008, the emission of natural gas increased in relation to 2007. The substantial change over the two-year period can be partly ascribed to the fact that almost no maintenance or renovation works were conducted in 2007, whereas 2008 saw a slight increase in these activities. In case of certain types of repair work, the pressure in the pipe is reduced as much as possible. However, it is still necessary to discharge some natural gas. Consequently, installation works increase the volume of discharge to the atmosphere.

The figures in **Table 13** are based on metered and calculated values. Energinet.dk performs regular aerial inspections of the transmission grid, for example to observe any failure of crops, which may be a sign of leaks. Moreover, in densely built-up areas routine leak detection is carried out on foot using very sensitive gas metering equipment. No leaks were detected in 2008.

7.3 Energy consumption from the transmission of natural gas

For the transmission of natural gas, energy is primarily used to heat the natural gas in the M/R stations. The pressure of the natural gas is reduced at the 42 M/R stations in Energinet.dk's transmission grid. In order to compensate for the accompanying drop in temperature, the natural gas is heated prior to pressure regulation. Natural gas is used as a fuel for heating. The natural gas is burnt using high-efficiency burners in boilers. The calculated environmental impacts of this heat production for 2008 are shown in **Table 14**. Altogether, 7,705 tonnes of greenhouse gases calculated as CO_2 equivalents were emitted in connection with the heating of the natural gas in the M/R stations.

Tabel 14 Environmental impacts from natural gas heating at M/R stations in 2008.

Environmental impacts from natural gas heating at Energinet.dk's M/R stations in 2008		
Energy consumption (natural gas in boilers)	MWh	37,286
CO_2 (carbon dioxide – greenhouse gas)	ton	7,622
CH_4 (methane – greenhouse gas)	kg	2,013
N_2O (dinitrogen oxide – greenhouse gas)	kg	134
Total greenhouse gases (CO_2 equivalents)	ton	7,705
CO (carbon monoxide)	kg	3,758
NMVOC (unburnt hydrocarbons	kg	268
SO_2 (sulphur dioxide)	kg	40
NO_X (nitrogen oxide)	kg	5,638

Compressor stations are also a potential source of energy consumption in connection with natural gas transmission. There are no compressor stations in the Danish natural gas transmission system as the compression in the North Sea natural gas fields and the two natural gas storage facilities in Stenlille and Lille Torup is sufficient to transmit the natural gas through the Danish transmission grid. In the future, it may become necessary to install compressor stations as the transmission grid expands.

The internal consumption of natural gas for compressors on the platforms in the North Sea is not included in the statement of environmental impacts from natural gas transmission. However, an overview of energy consumption associated with the transmission of natural gas from the North Sea fields can be seen in the background report to Environmental Report 2009.

7.4 Odorant consumption

Natural gas from Danish fields in the North Sea is cleaned offshore of hydrogen sulphide down to a maximum level of 5 mg/Nm^3. The hydrogen sulphide is removed to minimise corrosion in the gas pipelines, and the natural gas is therefore almost odourless when it enters the transmission grid. Energinet.dk is therefore under a statutory obligation to add a special odorant to the natural gas for safety reasons. The odorant is very pungent and distinctive so that any possible gas leakage can be quickly detected by people in the vicinity. The odorant is added at Energinet.dk's M/R stations before the natural gas is fed into the distribution grid. The odorant also helps consumers detect leaks in pipes or installations. The odour resembles that of cylinder gas.

Table 15 Odorant consumption in the natural gas transmission grid in 2008.

Environmental impacts from the use of odorant in Energinet.dk's natural gas transmission grid in 2008		
Quantity of odorant consumed	litre	55,565
Sulphur dioxide - (SO_2 emissions)	kg	40,373

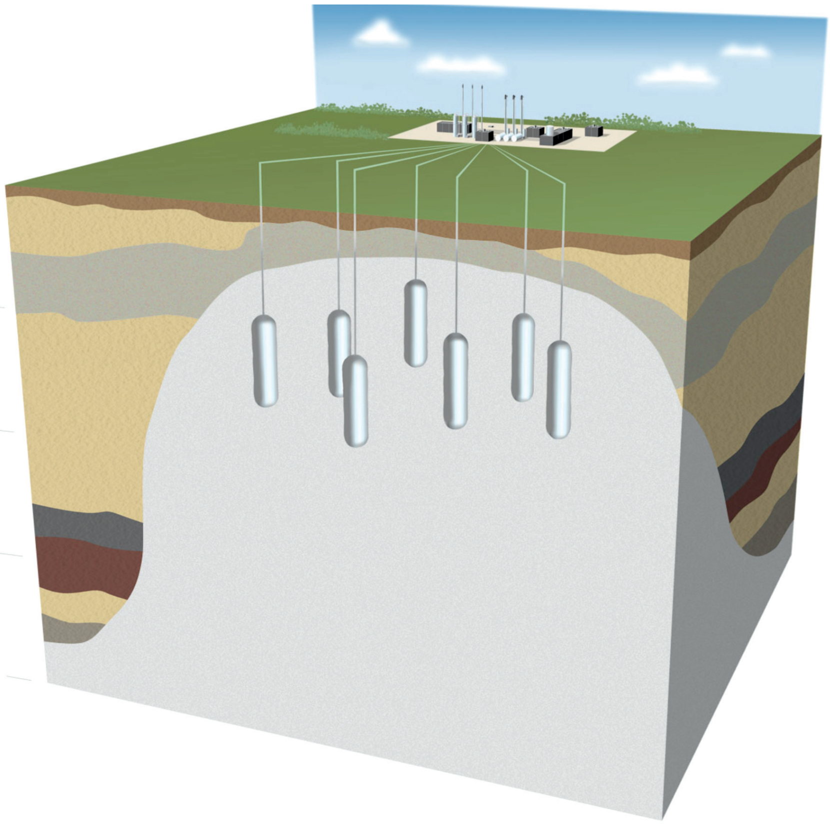
The odorant used is a sulphur compound (tetrahydrothiophene with the gross formula C_4H8S), and when it is burnt in connection with the end-use of the natural gas, the sulphur compound turns into SO_2, among other things, which subsequently contributes to the acidification of the environment. **Table 15** shows the consumption of odorant and the associated environmental impact of end-use in 2008.

7.5 Lille Torup natural gas storage facility

The natural gas storage facility is owned and operated by Energinet.dk Gaslager A/S, a subsidiary of Energinet.dk.

The gas storage facility comprises seven caverns, or cavities, located at a depth of up to 1.7 km below ground in a salt dome, see **Figure 15.** Natural gas can be pumped down into the caverns, and when all the caverns are full, the volume of gas stored corresponds to 10% of the annual gas consumption in Denmark. The principal activity of the Lille Torup facility is the storage of natural gas, partly to counterbalance differences in summer and winter consumption of natural gas and partly to serve as an emergency supply storage facility in case of an interruption in the natural gas supply from the North Sea. In summer, when consumption is low, the gas storage customers fill up the storage facility. In winter, when consumption exceeds daily production from the North Sea, the companies must use natural gas from the storage facility to supplement consumption. The natural gas storage facility was commissioned in 1987.

Figure 15 Drawing of Lille Torup natural gas storage facility, including salt dome and caverns.



Lille Torup natural gas storage facility is under a statutory obligation to prepare green accounts. The green accounts provide a statement of the facility's consumption of chemicals, paint, diesel, lubricating oils, etc; statements of waste and wastewater; emissions and consumption of natural gas as well as consumption of electricity for pumping natural gas down into the caverns. The green accounts for 2008 (Danish version) can be viewed at our website: gaslager.energinet.dk.

Textbox 5

Electricity consumption for compressing natural gas

Electrically-driven compressors are used to pump natural gas down into caverns at the natural gas storage facility. The statement for this electricity consumption is measured according to the energy content of the compressed natural gas. In 2008, 10,834 MWh were used to pump 307 million Nm^3 of natural gas down into the caverns at Lille Torup natural gas storage facility. The energy content of natural gas is 10.968 kWh/Nm^3; therefore the stored gas has an energy content of 3,367 GWh. The percentage consumption of compressing can thus be calculated at 0.32%.

Energy consumption and natural gas emissions from the natural gas storage facility depend on the volume of gas transmitted through the storage facility. **Table 16** shows the volume of natural gas transmitted in and out of the storage facility and its associated energy and gas consumption.

The compressors that pump the natural gas down into the caverns are electrically driven. Consequently, electricity consumption depends on the volume of natural gas injected into the storage facility. **Figure 16** shows this relationship over the past five years. The ratio of electricity consumption to injected gas volume is shown as a percentage of energy – a calculation example can be seen in **Textbox 5**. The figure shows that the percentage of the energy used for pumping the natural gas down into the caverns is very low when compared to the amount of energy stored as natural gas.

The natural gas is withdrawn from the storage facility by means of a simple pressure difference, as the pressure of gas in the cavern is higher than the pressure in the transmission grid. Consequently, the natural gas is automatically forced upwards. The gas condenses when stored in the caverns. Under certain operating conditions, triethyleneglycol is added to prevent the formation of ice crystals.

Before the pressure is reduced, the gas is heated and dried of water before being returned to the transmission grid. When the pressure is reduced, the heavier hydrocarbons in the gas condensate. This fraction, known as condensate, is used together with some of the natural gas to heat the remaining natural gas.

Figure 17 shows the ratio of natural gas consumption for boilers to the volume of natural gas withdrawn from the storage facility. Over the past five years, gas consumption for heating accounted for between 0.09% and 0.12% of the natural gas volume withdrawn, as condensate has not been included in the consumption. The value for 2008 includes the volume of condensate used; this additional consumption is shown as the hatched area in **Figure 17.**

Discharge gas consumption at Lille Torup natural gas storage facility is 144,396 Nm^3, see **Table 16.** The figure for the volume of discharged gas is high because Lille Torup emptied the gas pipes of natural gas in 2008 in connection with an interior inspection of the pipes.

Expansion of the natural gas storage facility

Energinet.dk is currently investigating the possibilities of expanding Lille Torup natural gas storage facility by adding up to nine new caverns. Besides establishing a number of additional cavern sites, Energinet.dk may also expand the above-ground treatment facility to include up to three new compressors and three new gas-drying plants. Investigations of the expansion project initially comprise the leaching of the existing seven caverns, which have shrunk by approx. 10% since they were established.

According to Energinet.dk' plans, the leaching will be performed with water from Hjarbæk Fiord, as was the case with the existing caverns. It takes about

Table 16 Resource consumption for natural gas storage in Lille Torup in 2008.

Environmental impacts of natural gas storage in 2008		
Natural gas injected into gas storage facility	million Nm^3	307
Natural gas withdrawn from gas storage facility	million Nm^3	329
Gas consumption for boilers	Nm^3	835,112
Gas consumption in connection with discharge	Nm^3	144,396
Electricity consumption	MWh	10,834

Figure 16 Resource consumption for natural gas storage in Lille Torup in 2008.

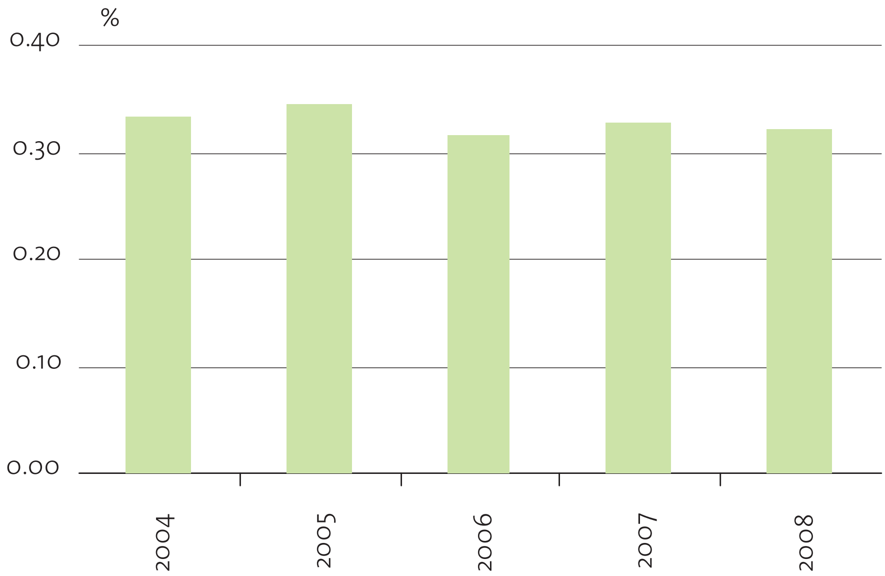
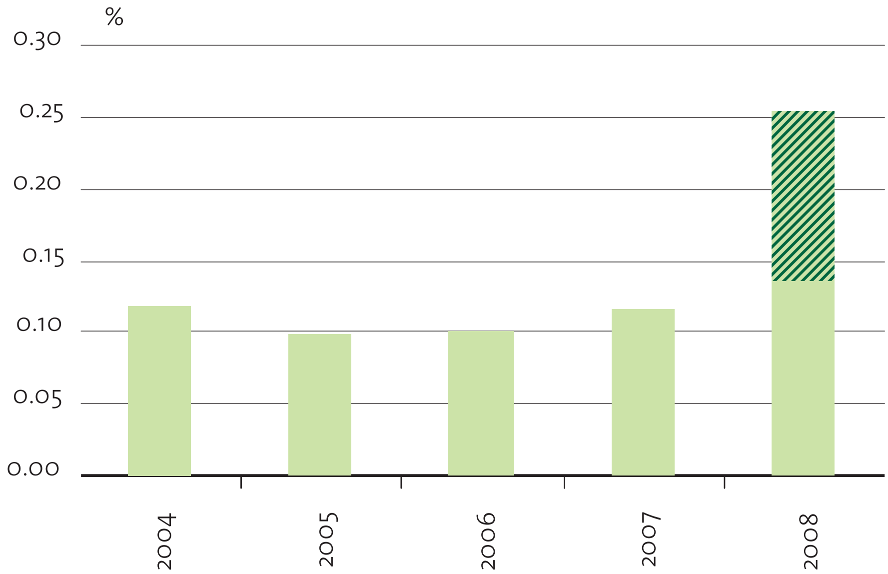


Figure 17 Ratio of natural gas consumption for boilers to natural gas volume withdrawn at Lille Torup gas storage facility. The hatched area is condensate used in the boilers.



three years to leach one cavern. The water is pumped into the salt dome dissolving the subterranean salt. The saline water is returned to the Liim Fiord so diluted that it will not pose a threat to the environment. The leaching of the existing seven caverns did not give rise to any specific evidence of environmental impacts on the aquatic environment.

Energinet.dk is planning to use the existing pumping station and discharge pipes. Environmental impacts will be observed in both the construction phase and during the normal operation of the storage facility. The actual permits, which - if granted - are going to be issued by the environmental centres of Aarhus and Ringkøbing, will specify approved environmental impact limits. Energinet.dk will take steps to ensure that impacts are kept within the approved limits and will for that purpose establish a monitoring and control programme.

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