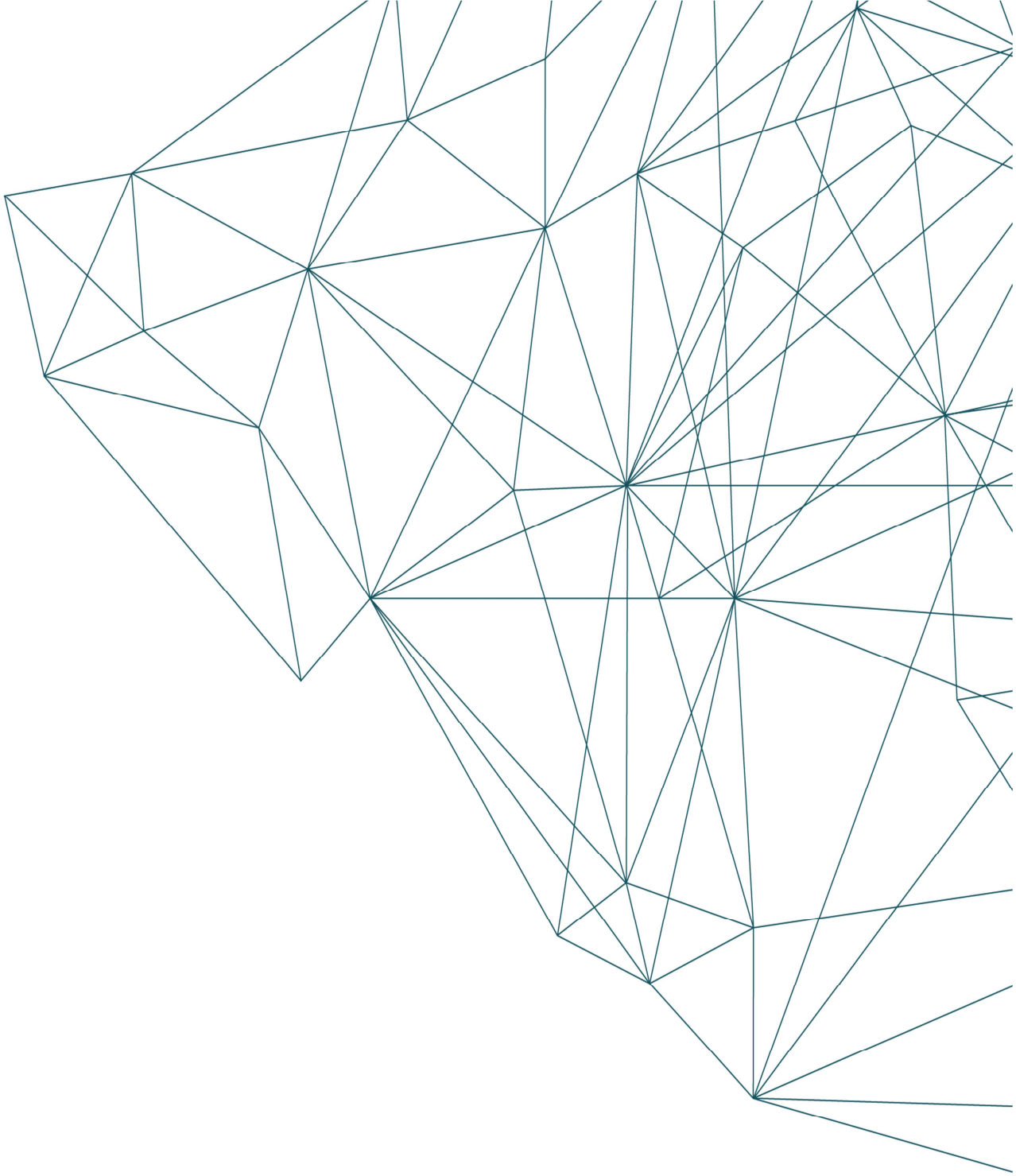


Environmental Report 2017

Environmental report for Danish electricity and CHP for 2016 status year

Contents

Pursuant to the Danish Electricity Supply Act, Energinet reports on the most important environmental issues associated with the generation of electricity and CHP in Denmark.

The report contains the following statutory descriptions:

- Status on environmental impacts from Danish electricity and CHP in 2016.
- Forecasts for 2017-2026 for electricity generation, fuel consumption and emissions to air.

For a further description of the methods and data basis including analysis assumptions for the Environmental Report, please refer to the individual documents at www.energinet.dk. More detailed data are available, including the data on which the figures are based.

The final analysis assumptions will be published after the presentation of this report, for which reason data discrepancies may occur. In the event of discrepancies, the analysis assumptions apply.

Electricity consumption and generation 2016

Developments in market and climatic conditions have a considerable bearing on the generation of electricity and CHP and thus on the environmental impact of these activities in Denmark. Special conditions in 2016:

- Electricity consumption in Denmark increased by 1.1 per cent from 2015 to 2016.
- Electricity prices were historically low in 2015 due to a high level of hydroelectric and wind power generation. The average Danish electricity price was approx. 18 per cent higher in 2016 as a result of lower water volumes in the Nordic region, less windy weather and increasing coal prices.
- With a wind index of 90.2, 2016 was a year with few wind resources. In comparison, in 2015 the energy content of the wind was 114 per cent.
- As was the case in 2015, the exchange capacity between western Denmark and Germany was constrained for long periods in 2016.

Table 1 and Table 2 show the change in selected electricity generation statistics in Denmark from 2015 to 2016. A more detailed breakdown of electricity generation can be seen in Table 5.

Key figures for electricity generation in Denmark	2015	2016	Change
	GWh	GWh	%
Net electricity generation	27,704	28,930	4
Net import	5,912	5,057	-
Consumption (including grid losses)	33,616	33,987	1.1
Breakdown of electricity generation	**GWh**	**GWh**	**%**
Electricity from central power stations	9,493	11,494	21
Electricity from local CHP plants	3,454	3,891	13
Electricity from wind turbines	14,133	12,782	-10
Electricity from photovoltaic cells	605	744	23
Electricity from hydroelectric power	19	19	3

Table 1. Change in power generation from 2015 to 2016.

In Denmark, there was a generation deficit of 5,057 GWh in 2016, which means that electricity generation was 15 per cent lower than consumption. The last generation surplus was seen in the dry year 2010. 2015 was a typical wet year with net exports to Germany and net imports from Norway and Sweden. In 2016, imports from Norway remained virtually unchanged at approx. 5 TWh, while a lower level of wind and hydroelectric power generation in Sweden meant that net imports from Sweden were replaced by net exports. Net exports to Sweden of 2 TWh in 2016 were offset by similar net imports from Germany.
After six years of increasing wind power generation in Denmark, wind power generation fell by 10 per cent from 2015 to 2016, which can be ascribed to less favourable wind conditions.

In 2016, electricity generation from photovoltaic cells totalled 744 GWh, corresponding to a 23 per cent increase on 2015. In the same period, photovoltaic cell capacity increased by 10 per cent. However, a number of large plants were installed at the end of 2015, which is the primary reason for the increased generation in 2016 as the full-year effect from these systems was not evident until 2016.

2015 was characterised by a historically low level of thermal electricity generation in Denmark. Higher electricity prices in 2016 led to increased generation from both local CHP plants and central power stations. However, in 2016 thermal electricity generation was still at the second-lowest level seen during the historical period for which data are available (1990 onwards).

Breakdown of electricity output by main fuel	2015	2016	Change
	MW	MW	MW
Wind power	5,080	5,251	170.3
Photovoltaics	779	851	72.0
Hydroelectric power	7	7	0.1
Biogas	113	112	-1.0
Biomass	887	1,502	615.0
Waste	341	351	10.7
Natural gas	2,153	2,148	-4.8
Oil	685	685	-0.5
Coal	2,219	1,604	-615.0
Other	26	26	0.0
Total	**12,289**	**12,536**	**246.9**

Table 2. Change in electricity output from 2015 to 2016.

Table 2 is based on Energinet's base data at year-end. Installed capacity is stated next to the power stations' main fuel. The figures do not include partly operational or preserved power stations.

The change in power station capacity was limited in 2016. Studstrup Power Station's unit 3 (360 MW) and Avedøre Power Station's unit 1 (255 MW) were, however, both commissioned at the end of 2016 following their conversion from coal to biomass, which also explains the change in the coal and biomass figures in Table 2.

Electricity consumption and generation 1990-2026

Figure 1 below shows the development in electricity consumption and generation in Denmark in the 1990-2026 period. The peaks in 1996, 2003 and 2006 were due to dry years with high market prices as a result of low water levels in Nordic reservoirs and thus increased power generation in Denmark.

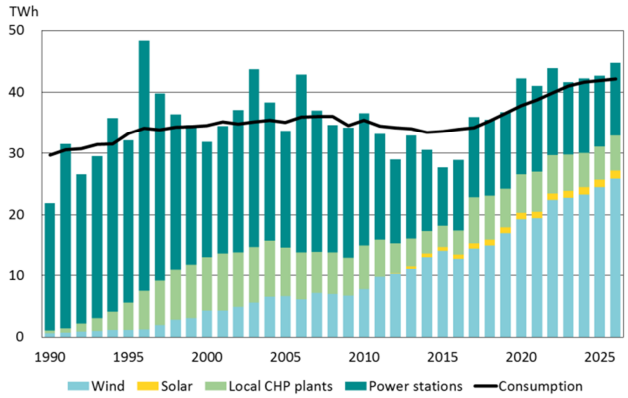


Figure 1. Electricity consumption and generation in Denmark

From 1990 to 2016, electricity consumption in Denmark increased by approx. 14 per cent, peaking at 36.1 TWh in 2008, but then followed by an approx. 6 per cent fall. The forecast is based on an increase in electricity consumption of just under 23 per cent. Part of this increase is explained by the expected establishment of several large data centres and the increased implementation of heat pumps and electric vehicles.

Central power station generation is expected to be at a higher level for the duration of the forecast period relative to the 2016 status year. The forecast period is characterised by the decommissioning of a large number of coal and natural gas-fired central power stations or the conversion of these power stations to firing with more biomass.

Local generation in Denmark grew steadily in the period from 1990 to 2000 in step with the increasing number of local CHP plants in Denmark. After 2004, local generation has been declining as many of the local CHP plants have started selling their electricity on market terms. At the beginning of the forecast period, local generation is expected to be higher than in 2016, followed by an assumed gradual decline towards 2026.

The 2012-2016 period saw a dramatic increase in the number of photovoltaic cells in Denmark. At the end of 2026, the estimated photovoltaic cell capacity is 1,337 MW. During the same period, the electricity generation from photovoltaic cells is expected to increase to approx. 1.3 TWh or 3 per cent of the expected future electricity consumption in Denmark.

There has been a great expansion of wind power in Denmark since 1990. In 2016, wind power thus covered approx. 37.6 per cent of the Danish electricity consumption relative to only 2 per cent in 1990.

Figure 2 shows the expected development in wind power generation towards 2026 (left axis). The curve shows the share of total electricity consumption based on wind power year by year (right axis).

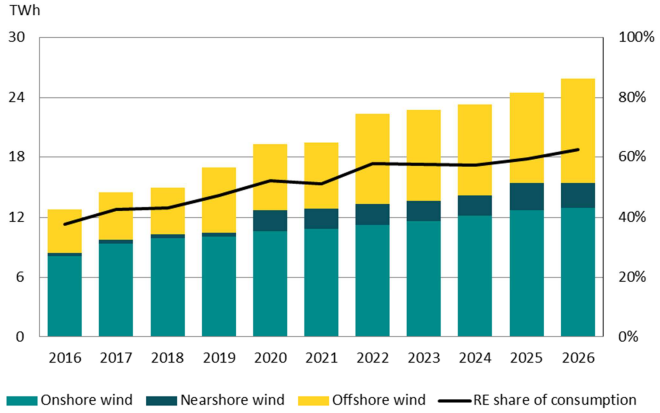


Figure 2. Wind power generation 2016-2026

The assumption is that there will be a considerable increase of wind power generation in Denmark in the period up to 2026. Total electricity generation from land-based, near-shore and offshore wind turbines in Denmark is expected to be 26 TWh in 2026, corresponding to approx. 63 per cent of electricity consumption in Denmark.

Much of the increase in wind power generation in the forecast period is expected to come from wind turbines at sea, partly from near-shore wind turbines and partly from three new offshore wind farms with total capacity of approx. 1,600 MW. In 2026, offshore wind power generation is expected to constitute approx. 50 per cent of the total wind power generation in Denmark, up from 36 per cent in 2016.

In 2026, electricity generation from land-based wind turbines is expected to be approx. 5 TWh higher than in 2016, which can be explained by an increase in both capacity and full-load hours (generation per installed MW). Some of the added land-based capacity will be counterbalanced by the decommissioning of other wind turbines, but the new land-based wind turbines are generally expected to have more full-load hours than the decommissioned ones.

Fuel consumption 2016

The development in the fuel consumption for the generation of electricity and CHP from 2015 to 2016 can be seen in Table 3.

Fuel consumption	2015	2016	Change
	PJ	PJ	%
Coal	72.85	83.90	15.2
Natural gas	22.23	25.84	16.2
Oil	3.11	3.30	6.2
Waste	35.06	34.94	-0.4
Biogas	4.71	4.82	2.5
Biomass	38.98	45.29	16.2
Total	176.94	198.09	12.0

Table 3. Change in fuel consumption from 2015 to 2016

Studstrup Power Station's unit 3 and Avedøre Power Station's unit 1 were both commissioned in 2016 following a conversion from coal to biomass, which can explain the increase in the consumption of biomass. The biomass conversions were implemented towards the end of the year, for which reason the full-year effect will not be evident until 2017. Going forward, the combined annual consumption of biomass by the two power station units is expected to be approx. 38 PJ.

Fuel consumption 1990-2026

A time series for the development in fuel consumption by Danish power stations and CHP plants for the period 1990-2026 is shown in Figure 3.

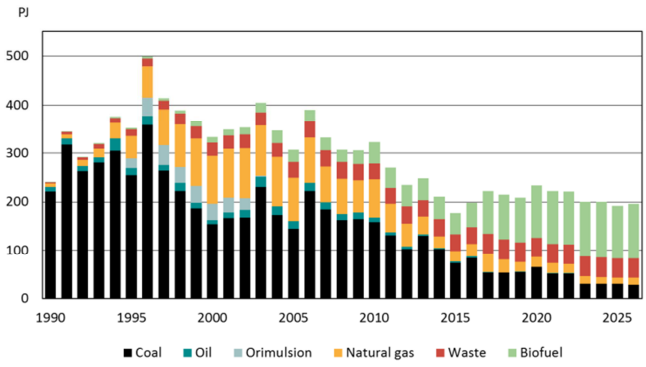


Figure 3. Fuel consumption in Denmark

From 1990 to 2016, coal went from accounting for 92 per cent to 42 per cent of fuel consumption for Danish electricity and CHP generation. This was due to an expansion of local CHP plants based on natural gas as well as the conversion of several power station units to natural gas and biomass. The consumption of coal has generally been decreasing since 1990, but variations are seen over the years as the coal-fired power stations have continuously adapted their output to demand.

Moreover, the period since 2010 has been characterised by a general fall in thermal electricity generation in Denmark and thus not least in the consumption of fossil fuels. While the consumption of waste and biofuels has been fairly constant from 2010 to 2016, the consumption of coal, natural gas and oil has decreased by 47 per cent, 67 per cent and 65 per cent during the same period.

In 2016, biofuels (biomass and biogas) accounted for 25 per cent of power station fuel consumption in Denmark. The consumption of biomass for electricity and CHP generation is expected to increase significantly in Denmark towards 2026. In fact, biofuels are expected to be the most commonly used fuels at Danish power stations from 2017. According to the forecast, the share of fuel consumption derived from biofuels will increase to 57 per cent in 2026.

A further reduction in the utilisation of fossil fuels by Danish power stations is expected in the forecast period as a number of central power stations are expected to be converted to firing biomass or decommissioned. Towards 2026, a gradual decrease in the capacity of local CHP plants based on natural gas has been assumed.

Renewable energy

Table 4 shows the development in renewable energy from 2015 to 2016.

Development in renewable energy	2015	2016	Change
	GWh	GWh	%
Net electricity generation	27,704	28,930	4
Consumption (including grid losses)	33,616	33,987	1.1
Breakdown of electricity generation	**GWh**	**GWh**	**%**
Wind, solar and hydroelectric power	14,757	13,545	-8
Electricity from thermal generation based on RE fuels	3,789	4,266	13
Electricity from thermal generation based on non-RE fuels	9,159	11,119	21
Share of renewable energy	**%**	**%**	**%-points**
Wind power share of net generation	51.0	44.2	-6.8
Wind power share of consumption	42.0	37.6	-4.4
RE share of net generation	66.9	61.6	-5.4
RE share of consumption	55.2	52.4	-2.8

Table 4. Development in renewable energy from 2015 to 2016.

Total electricity generation from renewable energy sources was 17,811 GWh in 2016 and constituted 61.6 per cent of total electricity generation in Denmark. Compared with 2015, the key figures for wind power share and the RE share declined in 2016 due to less wind power generation.

Share of renewable energy in 2016

Electricity generation from renewable energy sources in Denmark is dominated by wind power, but also includes electricity generated from hydroelectric power, photovoltaic cells, biogas, biomass (straw and wood) and biodegradable waste fractions. Figure 4 shows the breakdown of RE-based electricity generation in Denmark in 2016.

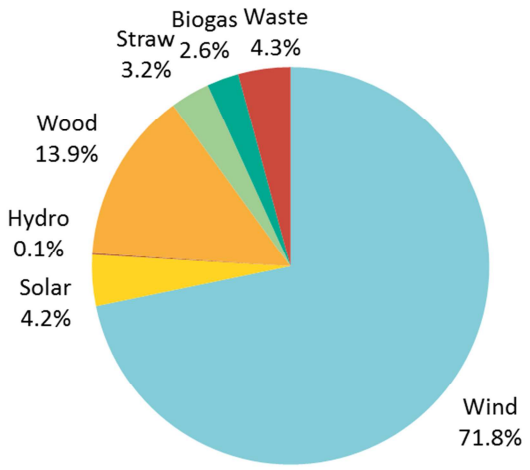


Figure 4. Breakdown of RE-based electricity generation in Denmark

Electricity generation from renewable energy sources 10 years ahead

Figure 5 shows the expected development in electricity generation from renewable energy sources in the next ten years (left axis). The curve shows the share of total electricity generation based on renewable energy sources year by year (right axis).

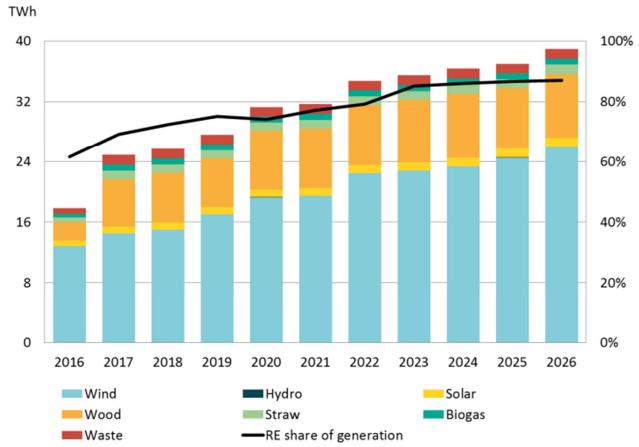


Figure 5. Electricity generation from renewable energy sources

The RE share of electricity generation in Denmark is expected to be increased to approx. 87 per cent in the course of the next ten years, which corresponds to more than a doubling of the current level of RE-based electricity generation.

The increase in RE generation is primarily expected to come from an increased expansion of wind power as well as the conversion of a number of central power stations to wood firing. In 2026, wind power is expected to account for two thirds of total electricity generation from RE sources, while wood is expected to account for 22 per cent.

CO_2, SO_2 and NO_x emissions

According to the most recent national statement from DCE – Danish Centre for Environment and energy from 2015 of total Danish emissions of CO_2, SO_2 and NO_x, the Danish electricity supply industry contributes 28 per cent, 23 per cent and 8 per cent, respectively.
The development in emissions of these three substances from Danish electricity and CHP generation in the period 1990-2016 is shown in Figure 6. Since 1990, emissions of CO_2, SO_2 and NO_x have fallen by 50 per cent, 98 per cent and 88 per cent, respectively.

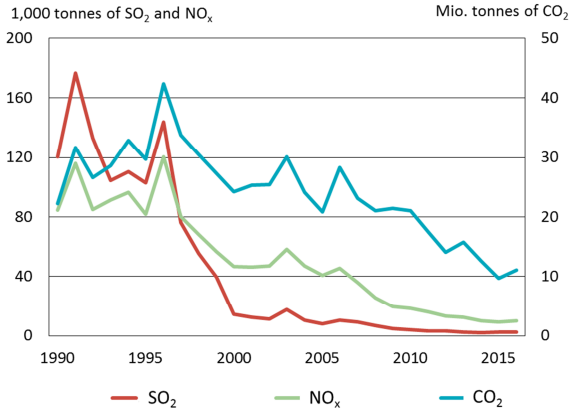


Figure 6. Emissions of CO_2, SO_2 and NO_x in Denmark

The decrease in SO_2 emissions since 1990 can be attributed to the use of fuels with a lower sulphur content and the installation of desulphurisation units at the large power stations and waste-fired plants. SO_2 emissions are so low that fluctuations in generation from individual power stations are clearly discernible. Despite the general improvements in the industry as a whole, increases in emissions may therefore be seen in some years. NO_x emissions have primarily been reduced through the installation of deNO_x units and low-NO_x burners at the large power stations.

Towards 2026, SO_2 and NO_x emissions are expected to remain at a consistently low level.

CO_2 emissions follow the development in the firing of fossil fuels at the Danish power stations, and substantial variations are therefore seen in the historical values, depending on Denmark's electricity trading with neighbouring countries.

The primary reason for the fall in CO_2 emissions since 1990 is the low electricity prices seen in recent years, which have led to a substantial decrease in thermal electricity generation based on fossil fuels. Also, over a number of years, Danish electricity and heat generation plants have been converted to less CO_2-intensive fuels such as natural gas, coupled with an increased use of renewable energy sources.

Figure 7 shows the development in CO_2 emissions from the Danish electricity supply industry in the 2016-2026 period (left axis). The curve shows specific CO_2 emissions per generated kWh of electricity in Denmark (right axis). Energinet does not make a projection of the environmental impact statement for electricity, which describes the environmental impact from the consumption of 1 kWh of electricity, and which is therefore corrected for exchanges of electricity with neighbouring countries.

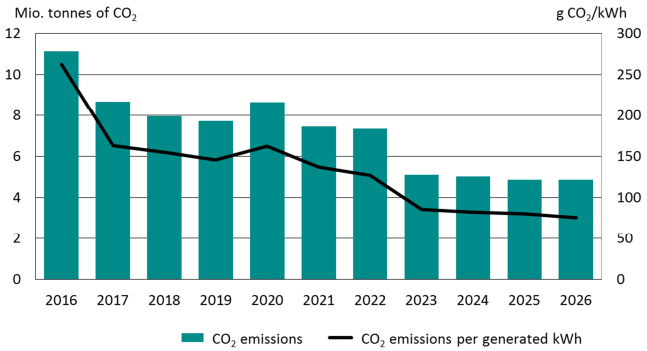


Figure 7. CO_2 emissions 2016-2026

A further 56 per cent reduction in CO_2 emissions is expected to be achieved by 2026 based on the assumed conversion of several central power stations from coal and natural gas to biomass as well as the anticipated gradual reduction of capacity at natural gas-fired local CHP plants.

The average CO_2 emissions from the generation of 1 kWh of electricity in Denmark in the same period are expected to decline from 262 g per kWh to about 75 g per kWh.

Other environmental impacts

In Table 5, Energinet also reports on emissions of the greenhouse gases CH_4 (methane) and N_2O (dinitrogen oxide) as well as particles, NMVOC (unburnt hydrocarbons) and CO (carbon monoxide). An overview of the generation of residual products is also available. Time series for the period 1990-2026 are also available for the above-mentioned environmental impacts on the Energinet website in the form of a spreadsheet.

Key figures for Denmark 2014-2016	Note	Unit	2014	2015	2016
Power generation (gross generation, including internal consumption)	1	GWh	32,161	28,931	30,199
Power supply to the grid (net ex plant)	2	GWh	30,615	27,704	28,930
CHP generation	3	TJ	91,330	93,573	97,881
Electricity imports		GWh	12,702	15,645	14,976
Electricity exports		GWh	9,847	9,733	9,919
Transmission grid losses (AC and DC)	4	GWh	876	963	969
Consumption (sale to distribution)		GWh	32,594	32,653	33,018
Specification of net electricity generation					
Electricity from land-based wind turbines		GWh	7,913	9,300	8,132
Electricity from offshore wind turbines		GWh	5,165	4,833	4,650
Electricity from photovoltaic cells	5	GWh	597	605	744
Electricity from hydroelectric power		GWh	16	19	19
Electricity from biofuels		GWh	3,078	2,998	3,508
Electricity from waste		GWh	1,441	1,438	1,377
Electricity from natural gas		GWh	2,188	1,912	2,366
Electricity from oil		GWh	126	151	169
Electricity from coal		GWh	10,091	6,449	7,964
Emissions to air from electricity and CHP generation					
CO_2 (carbon dioxide – greenhouse gas)	6	Tonne	12,561,796	9,678,013	11,118,114
SO_2 (sulphur dioxide – acidifying gas) total emissions		Tonne	2,018	2,533	2,410
SO_2 from units ≤ 25 $MW_{electricity}$		Tonne	1,023	1,626	1,382
SO_2 from units > 25 $MW_{electricity}$		Tonne	995	907	1,028
NO_x (nitrogen oxides – acidifying gas) total emissions		Tonne	10,096	9,049	9,819
NO_x from units ≤ 25 $MW_{electricity}$		Tonne	5,358	4,795	5,146
NO_x from units > 25 $MW_{electricity}$		Tonne	4,738	4,254	4,673
CH_4 (methane – greenhouse gas)		Tonne	5,110	4,330	4,904
N_2O (dinitrogen oxide – greenhouse gas)		Tonne	200	174	191
NMVOC (unburnt hydrocarbons)		Tonne	964	764	899
CO (carbon monoxide)		Tonne	6,764	6,166	6,959
Particles		Tonne	502	289	329
Fuel consumption for electricity and CHP generation					
Coal		TJ	102,543	72,851	83,895
Oil		TJ	2,376	3,109	3,300
Natural gas, including refinery gas		TJ	24,358	22,228	25,838
Biogas		TJ	4,739	4,707	4,824
Biomass		TJ	40,943	38,982	45,291
Waste		TJ	35,222	35,062	34,938
Residual products from electricity and CHP generation					
Coal fly ash		Tonne	461,118	332,179	366,003
Coal slag		Tonne	68,291	37,385	43,889
Gypsum		Tonne	124,361	91,707	98,844
Other desulphurisation products (SDAP)		Tonne	47,073	33,637	29,996
Bioashes		Tonne	53,976	56,711	55,588
Slag (waste incineration)		Tonne	606,764	597,093	609,136
MSWI-ACP residues		Tonne	95,422	92,339	90,103

Table 5. Key figures for Denmark 2014-2016

Notes

Note 1. Gross electricity generation corresponds roughly to the energy supplied by the generator at the individual generation facilities. Part of the gross generation is consumed before delivery to the grid. This includes the electricity used by the power station to operate pumps, environmental facilities etc.

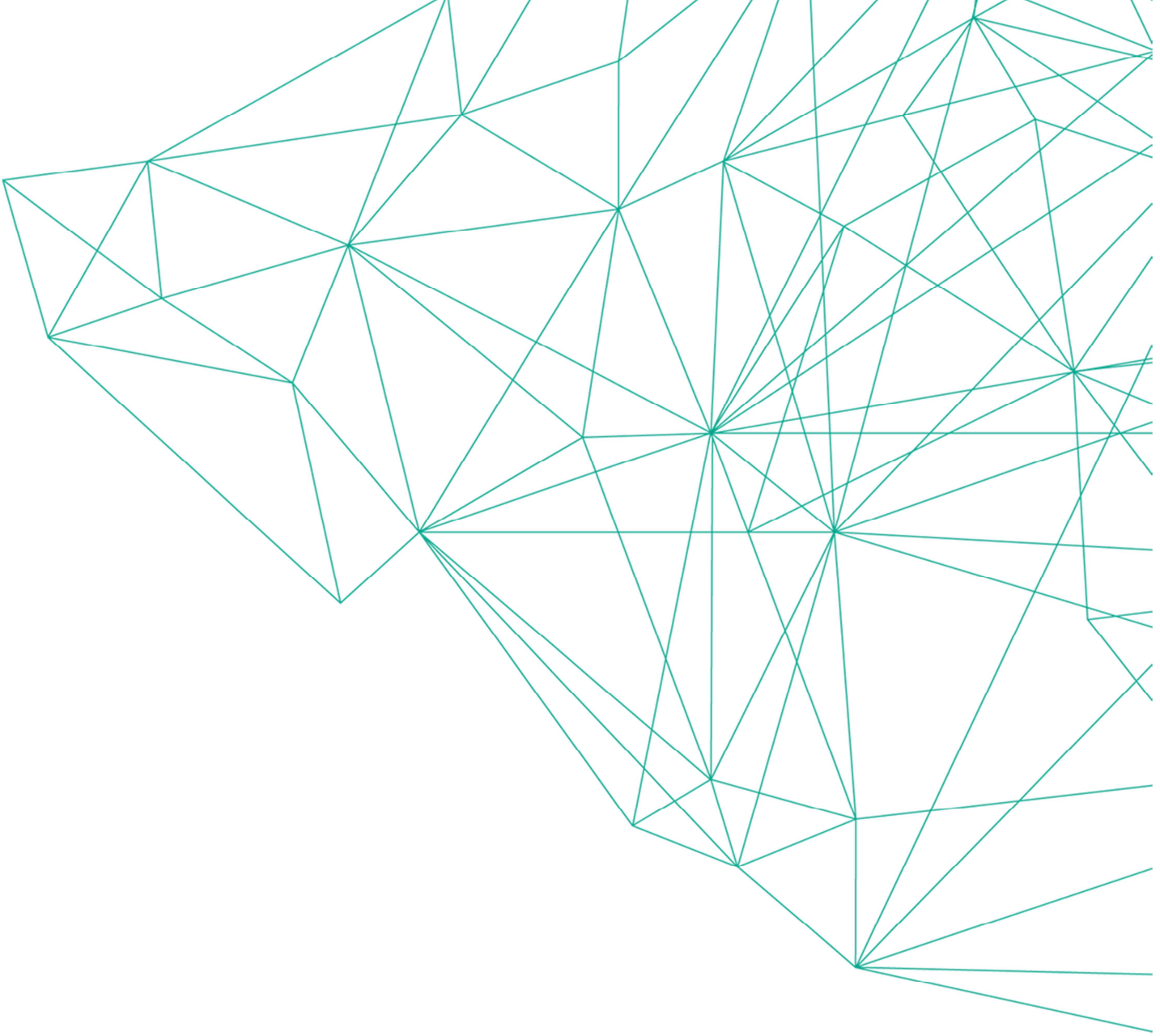
Note 2. The electricity supply is the volume of electricity from generation units available for domestic consumption or export via the grid. Electricity supplies are measured physically when discharged from the various generation units and recorded in Energinet's PANDA database.

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

Note 4. This grid loss concerns the transmission grid (400 kV, 150 kV and 132 kV), the Great Belt Power Link and the HVDC substations on the international connections. Transit losses from international connections are included in these losses.

Note 5. The electricity generated by photovoltaic cells includes an estimate of the generation from photovoltaic cell units subject to net settlement.

Note 6. Under the Danish CO_2 Emission Allowances Act, waste is considered CO_2-neutral. However, waste contains large amounts of plastic, which is made from fossil fuels. According to the most recent assessment from DCE, fossil elements account for 45 per cent of the energy volume of the waste. For the purpose of calculations, this corresponds to a CO_2 emission factor of 37 kg per GJ for waste.



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