Danish Energy Agency

2019

Denmark's Energy and Climate Outlook

Baseline Scenario Projection Towards 2030 With Existing Measures (Frozen Policy)

Denmark’s Energy and Climate Outlook 2019
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Glossary

Gross energy consumption: Gross energy consumption describes the total input of primary energy to the energy system. In statistical summaries, gross energy consumption may be adjusted for fuel consumption linked to foreign trade in electricity (adjusted for electricity trade), and for fluctuations in outdoor temperature relative to a normal year (climate-adjusted).

Final energy consumption: The final energy consumption expresses energy consumption delivered to end users, i.e. private and public enterprises as well as households. Uses include: manufacturing of goods and services, space heating, lighting and other appliance consumption as well as transport. Added to this is oil consumption for non-energy purposes, i.e. lubrication and cleaning as well as bitumen for paving surfaces. Energy consumption in connection with extraction of energy, refining and conversion is not included in final energy consumption. The definition and breakdown of final energy consumption follow the International Energy Agency's (IEA's) and Eurostat's guidelines. Energy consumption for transport by road and railway, by sea, by air, and by pipeline - irrespective of consumer - is subsequently taken out of the total final energy consumption figure as an independent main category. This means that energy consumption by industry and services and households is calculated exclusive of consumption for transportation purposes. Moreover, final energy consumption excludes cross-border trade in oil products, defined as the quantity of petrol, gas/diesel fuel and petroleum coke, which due to differences in price is purchased by private individuals and transport operators etc. on one side of the border and consumed on the other side of the border.

Gross final energy consumption: Energy products for energy purposes in industry and services, the transport sector, households, and the service sector, as well as energy products for agriculture, forestry and fisheries, including electricity and heating consumption by the energy sector in connection with electricity and heat production and including electricity and heat losses in connection with distribution and transmission. Thus, unlike final energy consumption, gross final energy consumption excludes consumption for non-energy purposes, including own consumption and distribution losses in energy supply as well as cross-border trade. Gross final energy consumption is used as the basis for calculating renewables' shares.

Observed (actual) energy consumption: Observed (actual) energy consumption is found by adding distribution losses and energy consumption in connection with energy extraction and refining to final energy consumption. Additionally, own consumption of energy in connection with production of electricity and district heating is added to this figure.

RE (renewable energy): Defined as solar energy, wind power, hydropower, geothermal energy, ambient heat for heat pumps and bioenergy (straw, wood chips, firewood, wood pellets, wood waste, bioliquids, biogas, biodegradable waste and bio-natural gas). Bio-natural gas is biogas that has been upgraded to meet the supply requirements for gas in the grid.

Renewables shares: Renewables shares are calculated according to the Eurostat EU calculation method. For a detailed description of this, see the Renewable Energy Directive (EU 2009) and Eurostat SHARES (Eurostat, 2018).

- RES: Total renewables share. Calculated as observed (actual) final domestic renewable energy consumption divided by gross final energy consumption.

- RES-E: Renewables share in electricity consumption. Calculated as the observed (actual) final domestic renewable energy consumption in electricity production, divided by domestic electricity consumption plus grid losses and own consumption. RES-E is included in calculations of other renewables shares. If RES-E exceeds 100%, a RES-E of 100% must be used in subsequent calculations.
- RES-H&C: Renewables share in heating and cooling consumption. Calculated as observed (actual) final domestic renewable energy consumption in production of district heating and district cooling plus industry and services and household consumption of other energy from renewable energy sources for heating, cooling and processing, divided by the sum of domestic final energy consumption as well as district heating/cooling production.
- RES-DH: Renewables share in district heating. Not defined in the Renewable Energy Directive, but calculated to supplement the other renewables shares. Calculated as the observed (actual) final domestic renewable energy consumption in district heating production divided by domestic district heating consumption plus distribution losses and own consumption.
- RES-T: Renewables share in transport. Calculated as observed (actual) renewable energy consumption for electricity used for transport purposes (up to 2020 based on RES-E two years ago, and, from 2021, based on RES-E for the preceding two-year period) plus consumption of biofuels divided by total fuel consumption for transport purposes using a number of multipliers. A distinction is made between uses and between first and second generation biofuels. Multipliers: 2x renewable energy from second generation biofuels and bio-natural gas for all modes of transport; 5x renewables share of electric road transport (4x from 2021); 2.5x renewables share of electric rail transport and other renewable energy (including hydrogen) (1.5x from 2021), as well as 1.2x renewable energy for sustainable biofuels used in aviation and maritime transport from 2021. The numerator is divided by total electricity and fuel consumption for transport using similar multipliers (except for the multiplier for electric road transport, which is only used in the numerator).

Greenhouse gases: Emissions of greenhouse gases are not measured but assessed using emission factors linked to emission activities such as fuel consumption, for example. These emission factors are adjusted regularly as new knowledge comes to light. When this happens, the projections and historical figures are also adjusted to produce a more correct presentation of historical emissions. This means that projections can vary solely on the basis of altered emission factors. In order to compare the climate impact of emissions, greenhouse gas emissions are converted into CO2 equivalents (CO2-eq.) corresponding to their climate impact. Primary greenhouse gases are:

- CO_2 (carbon dioxide, literally referred to as CO2): Primarily burning of fossil fuels such as coal, oil and natural gas.
- CH_4 (methane): Primarily organic processes such as the digestion system of animals and waste composting.
- N_2O (nitrous oxide): Primarily nitrogen conversion.
- F gases: Primarily chemical processes.

Greenhouse gas emissions covered by the EU ETS system (ETS): ETS emissions include emissions from energy production, heavy industry, aviation and other large point sources. The total number of emission allowances is set at EU level and this number is tightened annually. The allowances are traded on a common European market. Companies trade in emission allowances on the market, which means that direct regulation of emissions from the ETS sector cannot be implemented at national level.

Greenhouse gas emissions NOT covered by the EU ETS system (non-ETS): Non-ETS emissions primarily stem from transport, agriculture, households, other industries, waste, and a number of small-scale CHP plants, i.e. numerous large and small emissions sources. Regulation takes place through national initiatives by the individual countries which have received reduction targets relative to 2005 levels. The base year is 2005, as this year was the earliest year with data that made it possible to distinguish between ETS and non-ETS emissions. The European effort is shared between Member States according to an agreement for the periods 2013-2020 and 2021-2030.

Energy intensity: Energy intensity is a measure of the efficiency of energy use within the economy and is calculated as the relationship between energy consumption and financial output.

Biofuels: Biofuels are fuels produced from biological materials. Since 2010, biofuels have been mixed with fuels (petrol, diesel and natural gas) sold for land transport purposes. A distinction is made between first and second generation biofuels. First generation biofuels are primarily bioethanol and biodiesel produced on the basis of food crops. Bioethanol is typically produced from crops containing starches and sugar, such as cereal and sugar cane, while biodiesel is typically produced from oil crops, such as rapeseed, soybean and palm. Second generation biofuels are typically produced from residual products from agriculture and industry.

Abbreviations

Appls.	Appliances
CO2-eq., CO2e	CO2 equivalents
DCE	Danish Centre for Environment and Energy, Aarhus University
DEA	The Danish Energy Agency
DECO18	Denmark's Energy and Climate Outlook 2018 (last year's Outlook)
DECO19	Denmark's Energy and Climate Outlook 2019
DK1	Electricity price area 'Western Denmark'
DK2	Electricity price area 'Eastern Denmark'
Eff.	Efficiency
ENTSO-E	European Network of Transmission System Operators for Electricity
ETS	The European Emission Trading System
EU+24	The 24 countries in the electricity market model are grouped into 15 market areas: DK1, DK2, NO, SE, FI, DE-AT-LU, NL, GB-NI-IE, FR-BE, ES-PT, CH, IT, EE-LV-LT, PL-CZ-SK, HU
GDP	Gross domestic product
GWP	Global Warming Potential
HP	Heat pump
IEA	International Energy Agency
LTM	National Transport Model (Technical University of Denmark)
LULUCF	Land Use & Land Use Change & Forestry
MAF	Mid-term Adequacy Forecast - ENTSO-E
MoF	The Danish Ministry of Finance
MSW	Municipal solid waste
MWe	MW electricity (electric power)
NECP	National Energy and Climate Plan for the EU
Non-ETS	Not covered by the EU Emission Trading Scheme
PPA	Power Purchase Agreement (bilateral electricity trade agreement between the producer and the consumer)
PSO	Public Service Obligations (financing system to support electricity production from renewable energy sources and small-scale CHP)
RE	Renewable energy
RES	Renewable Energy Share - total renewables share
RES-DH	Renewable Energy Share - District Heating – renewables share in district heating consumption.
RES-E	Renewable Energy Share - Electricity - renewables share in electricity consumption
RES-H&C	Renewable Energy Share - Heating and Cooling – renewables share in heating and cooling consumption.
RES-T	Renewable Energy Share - Transportation – renewables share in transport consumption
TYNDP	10-year Network Development Plan by ENTSO-E
Waste (bio)	The biodegradable share of combustible waste.
Waste (fossil)	The non-biodegradable share of combustible waste.

1 Welcome to Denmark’s Energy and Climate Outlook 2019

Denmark’s Energy and Climate Outlook (DECO19) is a technical assessment of how Denmark’s energy consumption and production, as well as Denmark’s greenhouse gas emissions, will evolve over the period up to 2030 based on the assumption of a frozen-policy scenario.

A frozen-policy scenario describes a scenario with existing measures, i.e. a scenario in which no new policies are introduced.

DECO19 is therefore the Danish Energy Agency's best guess at what the future will be if *no* new measures are decided in the climate and energy area other than those adopted by the Danish Parliament by the end of May 2019.

The methodology behind the projections in DECO19 is well-defined and is based primarily on technological costs and on rational options and financial viability requirements of players in given markets (Danish Energy Agency, 2019a). At the same time, existing projects are also included if there is an approved application or funding commitment, for example for the conversion of a power plant from coal to biomass.

The assumed 'policy freeze' pertains to the climate and energy area only and does not imply that development in general will come to a halt. For example, economic growth and demographic trends are not part of the freeze.

DECO19 helps to examine the extent to which Denmark's climate and energy targets and commitments will be met within the framework of current regulation.

DECO19 can thus be used as a technical reference when planning new measures in the climate and energy area, and when assessing the impact of such measures.

1.1 What are Denmark's targets and commitments in the climate and energy area?

The climate and energy area is characterised by local, as well as by national and international targets and commitments. Most recently, the Social Democratic Party, the Danish Social-Liberal Party, the Socialist People's Party and the Red-Green Alliance formulated a target to reduce Denmark's greenhouse gas emissions by 70% in 2030 compared with 1990 (A *et al.*, 2019). The more specific framework for this target has not yet been established and, therefore, no shortfall figure has been calculated for this target.

This year’s Climate and Energy Outlook focuses on the target framework set out in EU legislation. This is because the results in DECO19 will be included in Denmark's National Energy and Climate Plan (NECP) to be submitted to the EU at the end of 2019 (European Commission, 2019a).

In 2009 the EU Climate and Energy Package was adopted and in December 2018 the Winter Energy Package was adopted. The Climate and Energy Package obligates Denmark to achieve, as a minimum, a total renewables share of 30% by 2020; a renewables share of 10% in transport by 2020; and a 20% CO2 reduction in non-ETS greenhouse gas emissions in 2020 relative to 2005.

The Winter Energy Package stipulates that, by 2030, the EU as whole must have reduced its greenhouse gas emissions by at least 40% relative to 1990; that the renewables share must be at least 32%; and that EU energy efficiency must have been improved by at least 32.5%[1] (European Commission, 2018a). For greenhouse gas emissions within the ETS system, it has been decided that the EU must reduce emissions by at least 43% by 2030. For greenhouse gas emissions outside the ETS system (non-ETS), Denmark is under a national obligation to reduce emissions by 39% by 2030, following a fixed reduction trajectory.

Under the Winter Energy Package, Denmark is required to report on its obligations in Denmark's National Energy and Climate Plan (NECP) to the EU. DECO19 and the upcoming NECP will form the basis for the European Commission's statement of whether Member States are making sufficient contributions to meeting overall EU targets for 2030.

1.2 What is new in DECO19?

Denmark's Energy and Climate Outlook changes from year to year. This is due to the introduction of new regulation that impacts the climate and energy area. However, updates to the detailed technical-economic assumptions behind the outlook are also an important factor and include updates to developments in fuel prices and the carbon price, new statistics on the composition of electricity and heat production, the total number of vehicles on the road, and agricultural production. Appendix 1 lists the general updates made in DECO19.

For example, last year, in DECO18, the Danish Energy Agency increased the expectations regarding future electricity consumption by large data centres. These expectations have been maintained in DECO19 and reflect an overall expectation for this sector that is not tied to decisions by individual players on individual projects, for example Apple's decision in June 2019 not to establish a data centre in Aabenraa in Southern Denmark (Aabenraa Municipality,2019). As in DECO18, the projection of electricity consumption by large data centres is still assessed to be associated with considerable uncertainty (COWI A/S on behalf of the Danish Energy Agency, 2018).

The most substantial changes in DECO19 compared with DECO18 are attributable to the effect of the Energy Agreement of 29 June 2018. Among other things, this agreement ensures financing of three offshore wind farms, relaxation of electricity taxes, new technology-neutral tenders, removal of the cogeneration requirement in small-scale district heating areas, new energy saving efforts, etc. (Ministry of Energy, Utilities and Climate, 2018). Other effects are attributable to new EU regulations imposing stricter emissions standards for passenger cars and vans (European Commission, 2019b) and heavy-duty vehicles (European Parliament, 2019).

DECO19 therefore reflects the expectation that both national and international regulations are to have a significant impact on developments in the climate and energy area.

However, there are also other factors influencing the area. DECO19 adjusts the expectation for the effect of a relatively new market product, the so-called PPAs (Power Purchase Agreements), which introduce new sources of financing to the electricity market. A PPA is a direct agreement between

[1] The energy efficiency target has been established in relation to the EU projection from 2007 and includes a obligation to achieve energy savings corresponding to 0.8% of final annual energy consumption (European Commission, 2018b).

an investor/producer and a major consumer on trade in a specific production of electricity. For example, a PPA may help provide major consumers with a guarantee of origin with respect to purchases of renewable energy to cover their electricity consumption. Based on its knowledge of a number of specific projects that are far into the implementation phase, the Danish Energy Agency can observe that businesses can increasingly see the value of social responsibility and they set voluntary renewable energy targets. Facebook's target of being 100% reliant on renewable energy in 2020 is an example of this (Facebook, 2019).

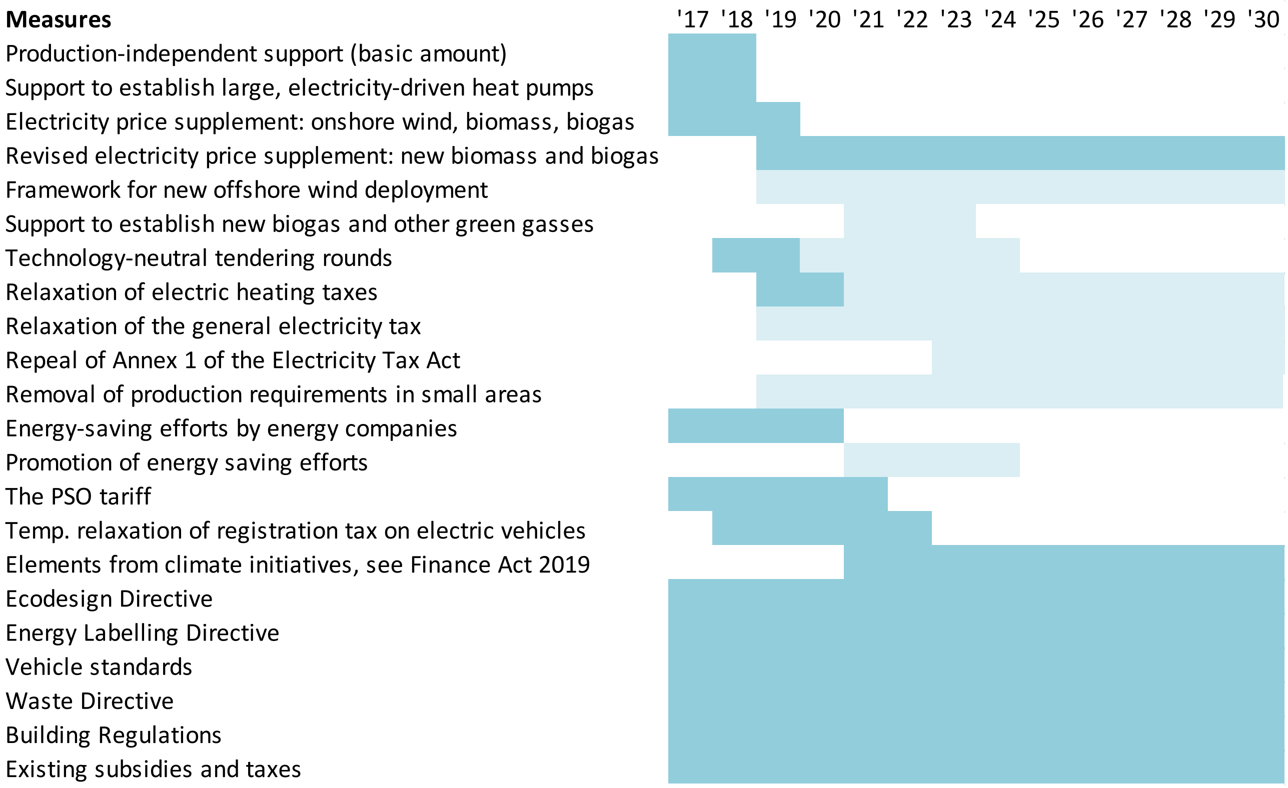
Studies and observations of the PPA market in combination with the technology-neutral tenders form the basis for DECO19's expectations regarding renewables deployment in the absence of new measures. This is particularly important in relation to expectations for new commercial solar PV (ground-mounted solar farms) and onshore wind. There is considerable uncertainty associated with projecting the deployment of commercial solar PV installations and the rate at which older onshore wind turbines are decommissioned.

1.3 Which regulation is of particular significance for DECO19?

Figure 1 illustrates the time range of impacts from regulations in the climate and energy area of specific significance for the projection.

Elements of the Energy Agreement of 29 June 2018 (Ministry of Energy, Utilities and Climate, 2018) are broken down by individual focus areas in the figure. Even though, in principle, the 2018 Energy Agreement is only in force for the period up to and including 2024, the time scope extends until 2030 for certain elements of the Agreement. For example, this applies to the framework conditions for new offshore wind deployment. The measures are described in Appendix 3.

Figure 1: The time scope for Danish regulation of special significance for the frozen-policy scenario in DECO19. Areas shaded in light blue reflect measures that are part of the 2018 Energy Agreement. See Appendix 3.



1.4 How has the Energy and Climate Outlook been prepared and calculated?

Denmark's Energy and Climate Outlook has been prepared by the Danish Energy Agency, assisted by an inter-ministerial monitoring group comprising the Ministry of Climate, Energy and Utilities, the Ministry of Finance, the Ministry of Taxation, the Ministry of Transport and Housing, the Danish Transport, Construction and Housing Authority, the Ministry of Environment and Food, the Danish Agricultural Agency, the Danish Environmental Protection Agency, the Danish Ministry of Industry, Business and Financial Affairs and the Danish Nature Agency.

In order to qualify the methodological and technical-economic basis for the model analyses in DECO19, the Danish Energy Agency has moreover consulted several experts and institutions.

The results presented in DECO19 are based on the integrated model platform for projections and impact analyses in the energy and climate area developed by the Danish Energy Agency since 1984. Figure 2 shows the overall elements in the model platform, with inputs on the left and outputs on the right. The figure and the model platform are described in more detail in Appendix 4.

The model platform is being regularly improved. For example, DECO19 uses a newly developed investment model for small-scale district heating areas. This model provides an improved approach to making projections about new investments as well as about decommissioning of existing facilities in the district heating sector.

On the basis of the Danish Energy Agency's system analyses, the Danish Centre for Environment and Energy (DCE) at Aarhus University models emissions of greenhouse gases for fuel consumption and non-energy-related activities (Aarhus University, 2019). Non-energy-related activities include agriculture as well as waste management, wastewater treatment and industrial processes.

1.5 Managing sensitivities and uncertainties

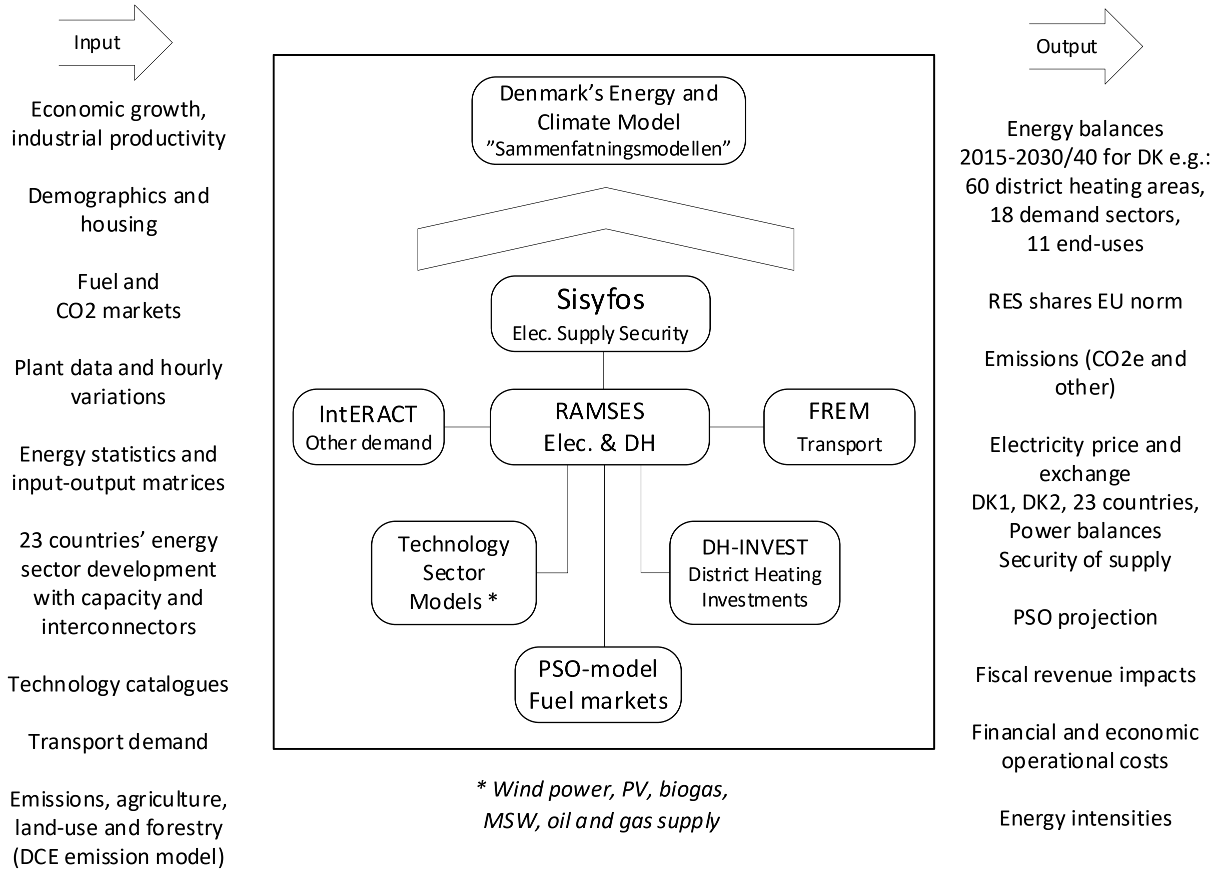
DECO19 presents a baseline scenario up to 2030 using a central set of assumptions which the Danish Energy Agency assesses to be the most probable in the absence of any new measures and on the basis of current knowledge.

It is important to consider that these assumptions and uncertainties affect the key results in this outlook report.

Several particularly sensitive assumptions have been identified, for example assumptions regarding the electricity consumption of data centres, changes in the carbon price, elements of renewables deployment and the deployment of electrified vehicles. As a result of this, partial sensitivity analyses have been completed, which means that a sensitivity analysis has been performed for each sensitivity parameter 'all else being equal'. The resulting partial sensitivity effects cannot readily be aggregated, i.e. the effects cannot be added together. The probability of variation in the individual sensitivities has not been assessed, nor has an overall risk analysis been performed.

The results of the partial sensitivity analyses are summarised in Chapter 8.

Figure 2: The Danish Energy Agency's integrated model platform for energy and climate projections. See the Danish Energy Agency website for descriptions and documentation of the sub models (Danish Energy Agency, 2019h). Elements in the model platform are described in more detail in Appendix 4.



1.6 Background appendices and data can be downloaded

The detailed central assumptions behind projections, such as assumptions concerning deployment of onshore wind, solar PV and biogas, accompany this report as a number of background appendices (Danish Energy Agency, 2019a).

Tables behind the results are included as a spreadsheet (Danish Energy Agency, 2019b). Results values for 2018 and 2019 have been omitted from the tables for reasons described in Appendix 5.

The background appendices and results figures and tables can be downloaded from https://ens.dk/outlook (Danish Energy Agency, 2019e).

2 The overall picture

- In 2030, Denmark's greenhouse gas emissions are expected to be reduced by 46% compared with the UN base year 1990 in the absence of new measures.

- The EU obligation for the non-ETS sector (non-ETS) will be met and exceeded for 2013-2020. For 2021-2030, an accumulated shortfall of 28 million tonnes CO2-eq. is expected.

- Emissions from LULUCF (land use and forestry) are expected to have fallen from 5 million tonnes CO2-eq. in 1990 to just over 3 million tonnes CO2-eq. in 2030. For the period 2021-2030 there is a preliminary basis for including an overall LULUCF contribution of 14.6 million tonnes CO2-eq. in Denmark's reduction efforts in non-ETS. The LULUCF statement is subject to considerable uncertainty.

- The total share of renewables (RES) is expected to be 54% in 2030. In 2020, the renewables share is expected to be 41%, whereby Denmark will have met, and exceeded, its EU obligation of 30%.

- The renewables share of electricity consumption (RES-E) is expected to exceed 100% from 2028 and reach 109% in 2030. This is due in particular to deployment of offshore wind, onshore wind and solar PV.

- The percentage of renewable energy in transport (RES-T) is expected to reach 19% in 2030, which is contingent on increased use of electricity to run railways and passenger cars and vans, as well as a high percentage of renewable energy in electricity consumption (RES-E). RES-T is expected to be 9% in 2020, which means that with no new measures Denmark will not meet its EU obligation of 10% renewables in transport.

- Consumption of coal is expected to be reduced by 90% in 2030 compared with 2017.

- Final energy consumption will increase by 0.4% annually, particularly due to increasing energy consumption in the service sector due to new electricity consumption by large data centres. Gross energy consumption will remain around 2017-levels.

- Electricity consumption (excluding grid losses) is expected to increase by 3% annually, which is due in particular to increasing consumption by large data centres and in heating, whereas increases in electricity consumption for transport will have only a minor effect on total electricity consumption.

- The macro-economic energy intensity measured as gross energy consumption is expected to fall by 1.2% annually, i.e. gross energy consumption is expected to increase by less than the economy.

- Uncertainties and assumptions subject to sensitivity affect the key results. For example, there is uncertainty associated with the projection of electricity consumption by large data centres, the carbon price, the number of dairy cattle, the level of coal-fired electricity production capacity, and the type of vehicles in the sale of new vehicles.

2.1 Total greenhouse gas emissions expected to be reduced by 46% in 2030

Since 1990, which is the UN base year for calculating climate efforts, total annual greenhouse gas emissions have fallen from 70.8 million tonnes to 50.6 million tonnes in 2017, corresponding to a reduction of 29%. Up to 2030, emissions are expected to drop to 38 million tonnes, corresponding to a reduction of 46% compared with the UN base year.

The projections show that total greenhouse gas emissions will be reduced by 46% in 2030 relative to the 1990 UN base year.

2.2 Achievement of non-ETS reduction targets 2021-2030 will fall short by 28 million tonnes CO2-eq.

Under the EU 2030 Climate and Energy Framework, Denmark is committed to reducing emissions from non-ETS sectors by 39% by 2030 relative to the 2005 level (European Commission, 2014, 2017b). The non-ETS sectors include transport, agriculture, households, waste, other industries, and a number of small-scale CHP plants.

Emissions in all years throughout the period 2021-2030 are expected to exceed the annual sub-targets. The accumulated shortfall has been calculated at 28 million tonnes CO2-eq. in 2030.

The projections show that, in the absence of new measures, Denmark will not meet its obligation to reduce greenhouse gas emissions in the non-ETS sectors for the period 2021-2030. In all the years, emissions are expected to exceed the annual targets and the accumulated shortfall for the entire period is expected to be 28 million tonnes CO2-eq. in the absence of new measures.

2.3 Total share of renewables (RES) expected to rise to 54% in 2030

Figure 3 shows the total share of renewables (RES) as well as renewables shares for transport (RES-T), electricity consumption (RES-E), heating and cooling (RES-H&C), and district heating (RES-DH), respectively, calculated on the basis of the method described in the EU Renewable Energy Directive (EU, 2009; Eurostat 2018).

The total renewables share (RES) and the renewables share for transport (RES-T) are subject to binding national EU targets in 2020. The EU Renewable Energy Directive also sets out a 2030 target for 27% renewables for EU countries together, but this target has not been implemented as national obligations. Instead, EU Member States are obligated to account for their contributions to reaching the common EU target in their National Energy and Climate Plans.

The projections show that the renewables share (RES) is expected to be 41% in 2020, whereby Denmark will have met, and exceeded, its EU obligation for a 30% renewables share by 2020.

The renewables share for transport (RES-T) will reach 9% in 2020, whereby there will be a shortfall of 1 percentage point compared with the RE Directive obligation of 10% in 2020.

The overall renewables energy share (RES) will increase up to 2030, when it will reach 54%. The trend depends on the deployment of offshore wind, onshore wind and solar PV and on the conversion of CHP plants to biomass, while energy-efficiency improvements in transport, industry and services and households will contribute to a lesser extent.[2]

The rate of renewables deployment in electricity supply is expected to exceed the rate of increase in electricity consumption, and Denmark's production of electricity from renewables is expected to exceed Denmark's electricity consumption from 2028. The renewables share of electricity consumption (RES-E) is expected to increase to 109% in 2030. This trend is particularly contingent upon the offshore wind farms included in the 2018 Energy Agreement being commissioned by 2030. There are also updated expectations regarding deployment of commercial solar PV (ground-mounted solar farms) and expectations regarding replacement of older onshore wind turbines with fewer, more efficient turbines.

The projection of onshore wind and solar PV deployment depends on the development in electricity prices (Chapter 6.5); maintenance of the level for tender prices achieved in the 2018 technology-neutral tendering round (Danish Energy Agency, 2019f); voluntary renewable energy targets from large consumers and the market for PPA/guarantees of origin (K2 Management for the Danish Energy Agency, 2019). This includes knowledge obtained by the Danish Energy Agency from municipalities and businesses about specific projects that are a long way into the preparation phase.

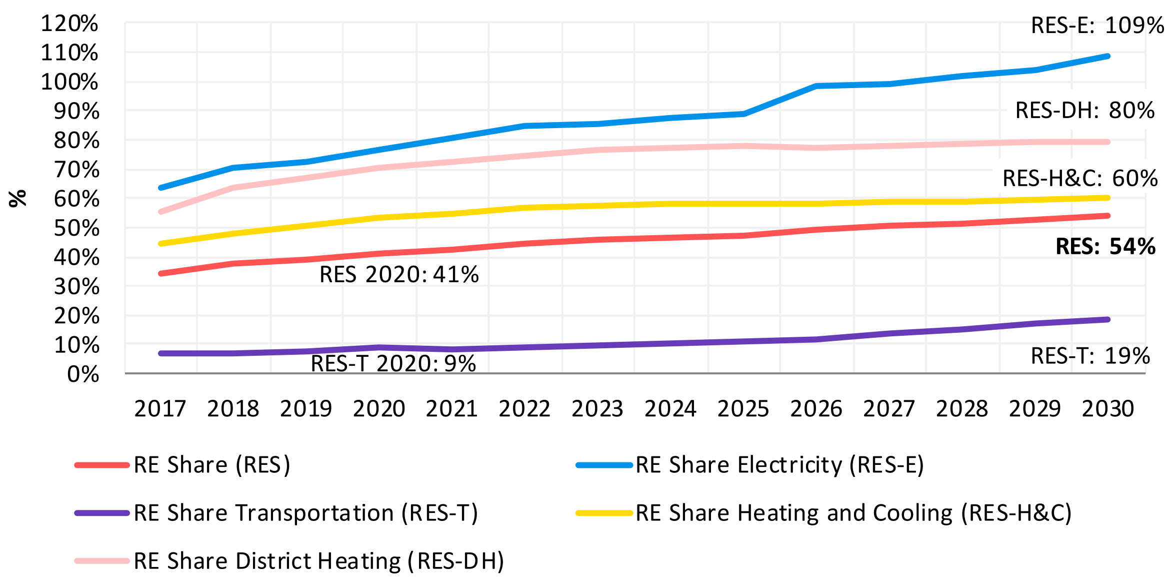
A high percentage of renewable energy in electricity consumption (RES-E) affects calculation of the renewables share in transport (RES-T) because the Renewable Energy Directive uses a multiplication factor of four for the renewables share of electric road transport and a multiplication factor of 1.5 for the renewables share of electric rail transport (see the glossary). With this background, RES-T increases to 19% in 2030, which is contingent on the number of electrified passenger cars and vans increasing to around 9% of the total number in 2030, and an increased use of electricity in rail transport. Greater use of bio-natural gas in transport will only contribute to a very limited extent. The blending ratio of biofuels in petrol and diesel is expected to be maintained at the current level in the absence of new measures.

Fuel consumption for domestic air traffic is included in the calculation of the renewables share. The aviation sector has announced ambitious plans for biofuel blending, but as these announcements are neither binding nor reflect a profitable development pathway for companies in the absence of new measures, the plans have not been included in a renewables contribution from this sector.

[2] The renewables share is calculated in relation to final energy consumption (denominator). Therefore, energy-efficiency improvements entail a higher renewables share, all else being equal.

The projections show that the total share of renewables (RES) is expected to reach 54% in 2030 in the absence of new measures. The renewables share of electricity consumption (RES-E) is expected to exceed 100% from 2028. A high RES-E affects the renewables share for transport (RES-T), which will reach 19% in 2030. The total share of renewables in 2020 meets and exceeds the Renewable Energy Directive, while the renewables share for transport in 2020 will be 1 percentage point short of meeting the EU obligation.

Figure 3: Renewables shares 2017-2030 [%]. The renewables shares is calculated as defined in the RE Directive (Eurostat, 2018).



2.4 Gross energy consumption maintained, coal consumption reduced significantly

Figure 4 shows that, since 1990, gross energy consumption has been relatively constant, with falling consumption of coal and increasing consumption of renewable energy. Gross energy consumption peaked in 2007 at 873 PJ and has since followed a downward trend.

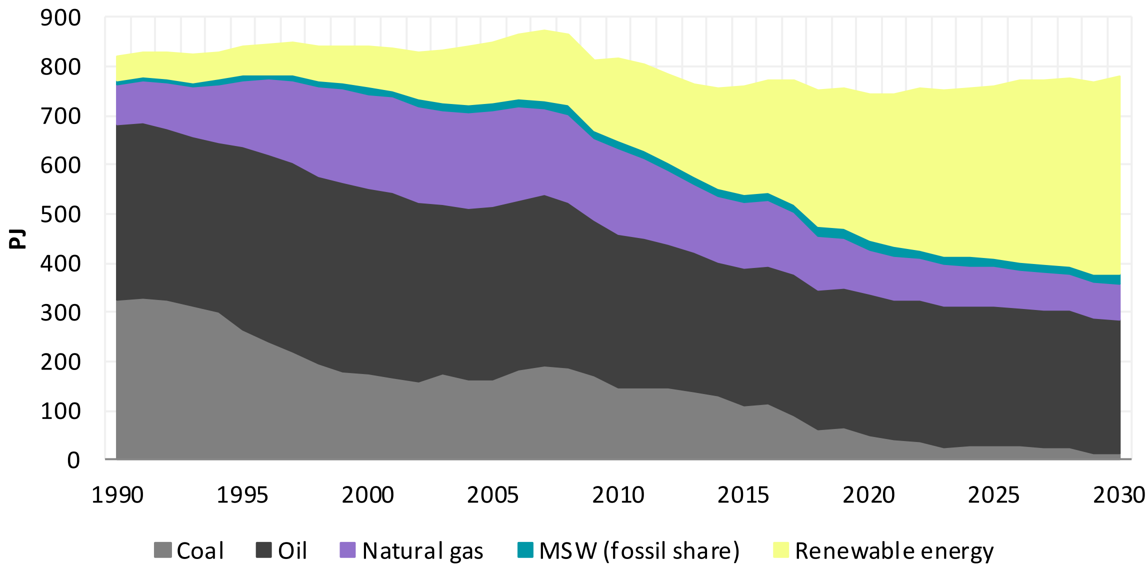
Gross energy consumption is expected to drop up to 2020 by 1.2% annually, after which gross energy consumption will rise slightly to 778 PJ in 2030, corresponding to the consumption in 2017.

Coal consumption will fall considerably up to 2030 by 14% annually, due in particular to the expected stop in the use of coal in large-scale CHP production.

In 2030, only the power station Fynsværket and the cement industry will consume large amounts of coal. However, some plants will retain the option for coal operation, although actual use is assumed to be limited.

The projections show that gross energy consumption will fall up to 2020, then rise slightly so that the 2030 consumption will be similar to the 2017 level. Consumption of coal is decreasing especially sharply, and by 2030 consumption will be more or less limited to the Fynsværket power station and in the cement industry.

Figure 4: Gross energy consumption by type of energy 1990-2030 [PJ]. The calculation for 1990-2017 has been adjusted for outdoor temperature/degree days relative to normal years (climate-adjusted) and electricity trade with other countries (electricity-trade adjusted, see Appendix 2).



2.5 Final energy consumption is growing, in particular for the service sector

Figure 5 shows that final energy consumption will increase to 671 PJ in 2030, corresponding to an annual increase of 0.4%.

Only energy consumption by households is expected to fall (by 0.5% annually), while for the other sectors energy consumption is expected to rise steadily. The largest increase will be in energy consumption in the service sector, which will increase by 2.8% annually, particularly due to expected new electricity consumption by large data centres (COWI A/S for the Danish Energy Agency, 2018). There is still considerable uncertainty associated with projecting electricity consumption by large data centres.

The service sector's share of final energy consumption will increase to 18% in 2030, which is almost the same as manufacturing industries at 20% in 2030.

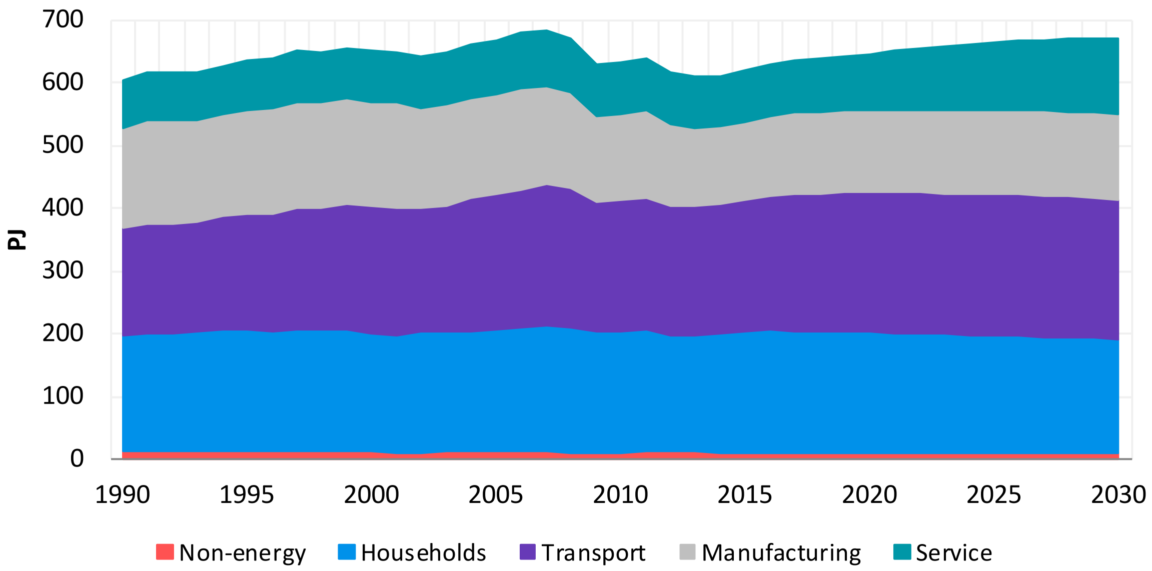
Energy consumption by manufacturing industries will increase by 0.4% annually as a result of economic growth in combination with the effect of energy efficiency measures.

Energy efficiency in industry and services is reflected in energy intensity, which expresses energy consumption in relation to the production value of industry and services. Total energy intensity in industry and services will fall by around 1% annually up to 2024, but the annual rate of reduction will halve from 2025 in the absence of new measures (Chapter 4.6).

Energy consumption by the transport sector will increase by 0.2% annually, primarily due to increasing transport volume.

The projections show that final energy consumption is expected to increase by 0.4% annually, particularly due to increasing electricity consumption by large data centres, which is included in energy consumption by the service sector.

Figure 5: Final energy consumption by consumption sector 1990-2030 [PJ].



2.6 Electricity consumption increases due to data centres and electrification of heating and transport

Electricity consumption and its composition will change up to 2030, depending, in particular, on the expected electricity consumption of large data centres and electrification within heating and transport.

Figure 6 illustrates that electricity consumption (excl. grid losses) will increase by 3% annually up to 2030.

COWI A/S has assessed the deployment of data centres on behalf of the Danish Energy Agency (COWI A/S for the Danish Energy Agency, 2018). On the basis of this assessment, expectations are maintained that electricity consumption by large data centres will increase to 25.3 PJ (7 TWh) in 2030.

Electricity consumption for space and domestic water heating will increase by more than 7.7% annually to 27 PJ (7.5 TWh) in 2030, which reflects expectations for more widespread use of heat pumps in households, district heating and in industry and services.

Electricity consumption for transport will increase to 7.5 PJ (2 TWh) in 2030 based on expectations for railway electrification and an increasing number of electrified vehicles in road transport.[3]

A total of 1,545 electric vehicles and 3,128 plug-in hybrid vehicles were sold in 2018, which together corresponds to 2.1% of the total sale of passenger cars, which was 218,565 (De Danske Bilimportører, 2019). There are also a number of electrified vans, buses and trucks. In the absence of new measures, sales of electric and plug-in hybrid vehicles are expected to increase to 22% of total annual sales of passenger cars and vans in 2030. With this backdrop, electrified vehicles are expected to account for almost 9% of the total number of passenger cars and vans on the road in 2030.

Figure 6 shows electricity consumption by use in 2030. It can be seen from the figure that data centres are expected to account for 15%, electricity consumption for heating 13%, and electricity consumption for road and rail transport is expected to account for 4%.

The projections show that electricity consumption is expected to increase by 3% annually, due in particular to increasing consumption by large data centres and for heating, whereas increases in electricity consumption by transport will have only a minor effect on total electricity consumption.

[3] Electrified vehicles comprise electric vehicles (BEV, EV) and plug-in hybrid vehicles (PHEV), while hybrid vehicles (HEV) are categorised in relation to their primary fuel (usually petrol).

Figure 6: Electricity consumption (excluding grid losses) by use 2017-2030 [PJ].

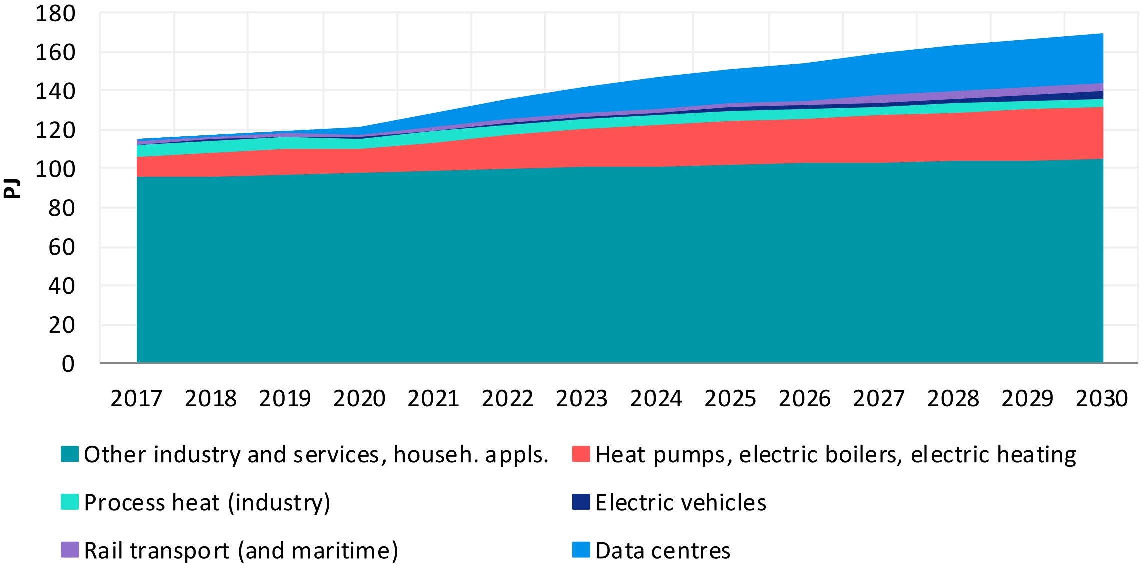
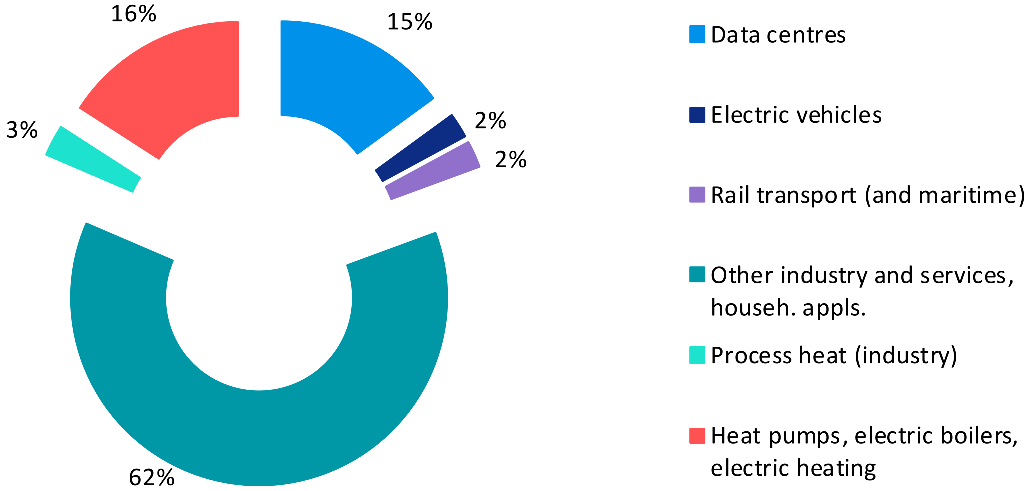


Figure 7: Electricity consumption (excluding grid losses) by use in 2030 [%].



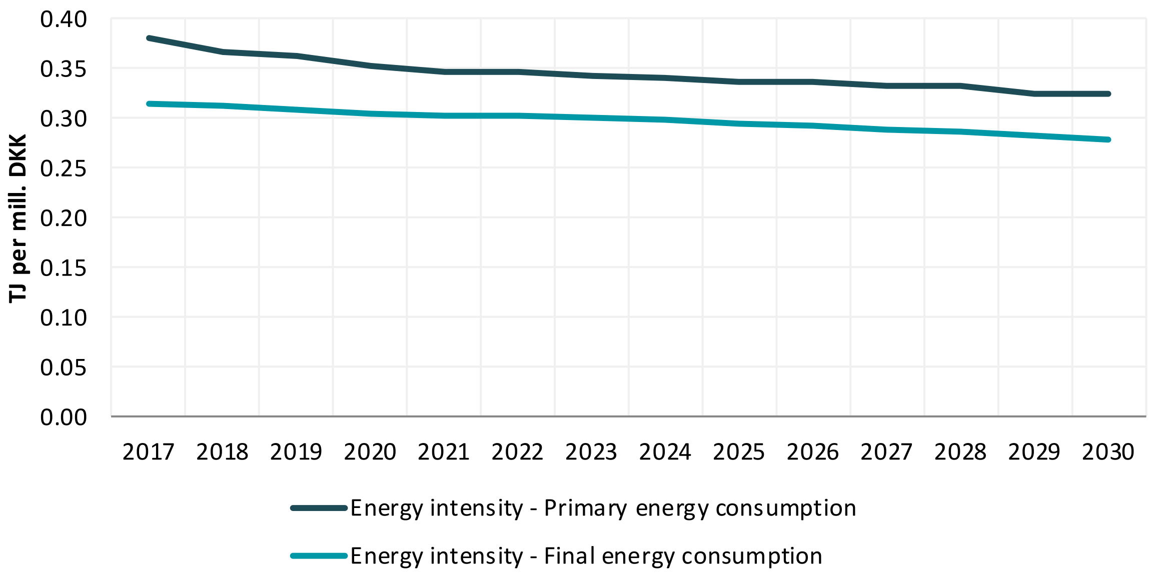
2.7 Macro-economic energy intensity is falling

Macro-economic energy intensity compares changes in energy consumption with changes in GDP. At a general level, energy intensity can help reflect developments in economic energy efficiency, although it does not serve to describe developments in technical energy efficiency.[4]

Figure 8 shows that energy intensity measured as gross energy consumption in relation to GDP is expected to fall from 0.38 TJ per DKK million to 0.32 TJ per DKK million in 2030, corresponding to an annual drop in energy intensity of 1.2%. Furthermore, the figure shows that energy intensity measured as final energy consumption is expected to fall by 0.9% annually.

The projections show that macro-economic energy intensity is falling (rising energy efficiency). Energy intensity measured as gross energy consumption compared with GDP is expected to fall by 1.2% annually.

Figure 8: Macro-economic energy intensity measured in relation to gross energy consumption and final energy consumption 2017-2030 [TJ per DKK mill.].



2.8 Sensitivities and methodological considerations

The projections are based on a number of central assumptions with associated uncertainties. Changes in these assumptions may have significance for the key results of the projections.

Possible consequences of selected sensitivities for the key results of the projections are described in Chapter 8.

[4] Energy intensity does not take account of energy consumption in international maritime transport and aviation, although these are included in GDP.

3 Energy consumption in households

3.1 Main points

- 83% of household energy consumption is used for space heating, the rest for electric appliances. Household energy consumption for heating is expected to fall by 0.6% per year, despite an expected increase in floor area of 0.5% per year over the period. This is particularly due to continued energy efficiency improvements in buildings and an expected shift to more efficient heating technologies, primarily heat pumps.

- Consumption of district heating is slightly declining but constitutes 44% of household energy consumption for heating in the whole period.

- In 2030, oil consumption for heating is expected to amount to less than 2% of final energy consumption for heating, which reflects that recent decades' phase-out of oil consumption for heating is expected to continue.

- Gas consumption continues to constitute a significant, but slightly falling, percentage of energy consumption for heating. Gas consumption is expected to drop by 1.6% per year and is expected to amount to 14% of energy consumption for heating in 2030.

- Recent years' increase in the consumption of wood pellets for heating is expected to have peaked, and consumption is expected to fall to 6% of energy consumption for heating in 2030.

- The contribution to space heating from heat pumps will increase by 7.4% annually. Heat pumps for heating purposes replace declining consumption of wood pellets, oil and gas, and will amount to 16% of energy consumption for heating in 2030.

- Electricity consumption for appliances is expected to increase by 0.3% annually from 2017 to 2030, while the number of electrical appliances will increase by 2.3% annually. This difference is especially due to electrical appliances becoming increasingly more efficient as a result of the EU Ecodesign Directive.

3.2 The overall picture

Final energy consumption by households was 30% of the total final energy consumption in 2017, and this is expected to fall to 27% in 2030. The share of energy consumption used for heating will be around 83% throughout the period. Other energy consumption by households is used for electrical appliances.

Figure 9 shows that consumption of district heating is slightly declining and constitutes 44% of household energy consumption for heating in the whole period.

Oil consumption for heating fell from 22% of household energy consumption in 2000 to 6% in 2017. In 2030, oil is expected to amount to less than 2% of final energy consumption for heating, assuming that recent decades' phase-out of oil consumption for heating continues.

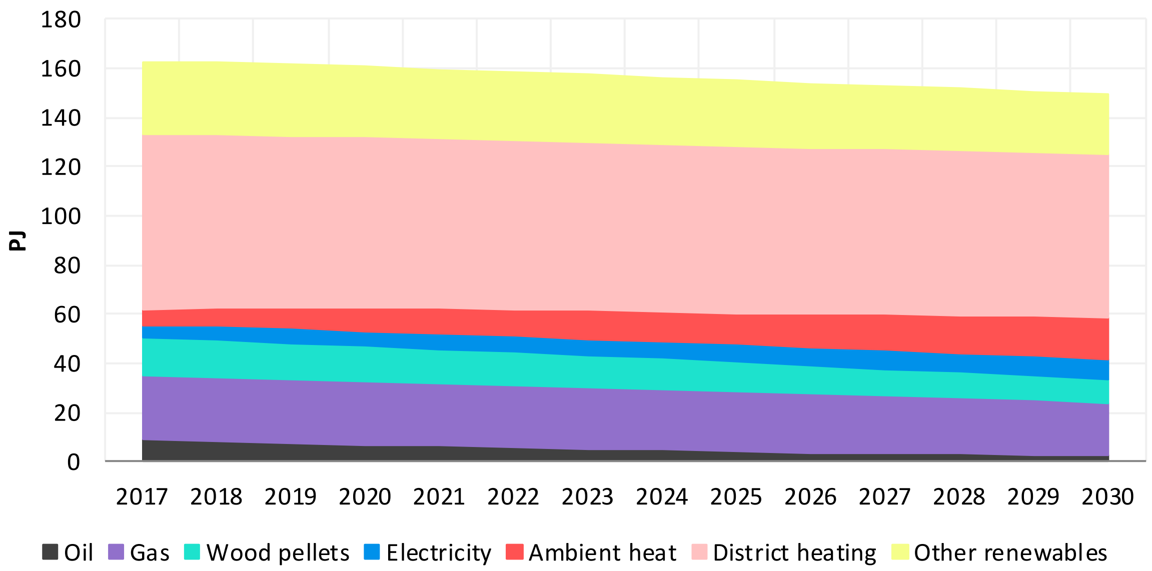
Up to 2003, households changed to gas in particular, but from 2004 onwards the change is more to wood pellets in particular. Figure 9 shows that the distribution of energy consumption by energy product is still changing. Up to 2030, wood pellet consumption is expected to fall by 3.5% annually, whereas consumption of oil and gas will fall annually by 9.3% and 1.6%, respectively. The falling consumption of wood pellets and fossil fuels will be offset by an increasing contribution from heat pumps, which will increase by 7.4% annually.

Other consumption of renewables will comprise fuel wood in particular and is expected to fall by 1.5% annually up to 2030.

Despite a rising number of electrical appliances, the associated electricity consumption has remained constant over the past 15 years. This is because electrical appliances have become more efficient, partly as a consequence of the EU Ecodesign Directive and the Energy Labelling Directive. In the projections, the number of appliances is expected to increase by 2.3% annually, while electricity consumption for these is expected to increase by 0.3% annually up to 2030.

The projections show that heat pumps will increasingly replace consumption of fossil fuels and wood pellets for heating, and that households will buy more electrical appliances but that these appliances will be more efficient.

Figure 9: Final energy consumption by households for heating 2017-2030 [PJ]. Gas comprises mains gas, i.e. natural gas, gas works gas and bio-natural gas. Other renewable energy includes firewood in particular, but also solar heating and straw.



3.3 Energy consumption for heating will fall despite an increase in heated floor area

Final energy consumption by households for heating is expected to fall to 150 PJ in 2030, corresponding to an annual 0.6% decrease. The total heated floor area is also expected to increase by 0.5% per year in the period.

Net space heating demand is expected to fall from 140 PJ in 2017 to 135 PJ in 2030. This fall is due to higher standards of insulation in new buildings, re-insulation of existing buildings and demolition of older buildings. This development is linked to tighter building regulations and energy saving efforts by energy companies up to 2020, as well as the expected effects of the new funding scheme for energy savings in buildings from 2021 to 2024.

The projections show that energy consumption for heating will fall, despite an increase in heated floor area. This primarily depends on tighter building regulations and energy saving efforts by energy companies up to 2020 and the expected effects of the new energy savings pool up to 2024.

3.4 Heat pumps more prominent in household heating

Up to 2030, heat pumps are expected to increasingly displace other heating technologies. This depends in particular on relaxations of the tax on electric heating in the 2017 Agreement on Business and Entrepreneurial Initiatives and in the Energy Agreement 2018 (Ministry of Energy, Utilities and Climate, 2018).

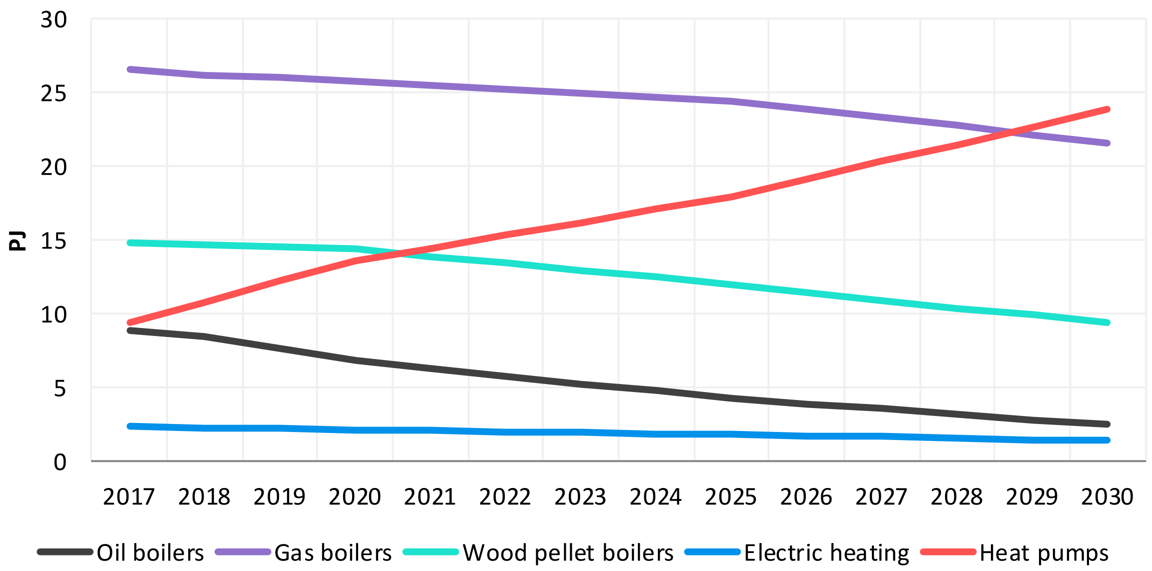
Figure 10 shows that consumption of oil, gas and wood pellets for heating is expected to fall up to 2030. After several years' increase, consumption of wood pellets is expected to fall by 3.5% annually, and will be at 9 PJ in 2030, corresponding to the 2006 level.

Heat pumps are expected to replace in particular consumption of oil and wood pellets for heating. The contribution from heat pumps will increase by 7.4% annually and exceed consumption of wood pellets from 2021. Electricity consumption for electric radiators is expected to fall to 1.5 PJ in 2030.

Gas is expected to continue to account for an important share of heating at 14% in 2030.

The projections show that heat pumps will replace declining consumption of fossil fuels and wood pellets. While consumption of oil will be almost phased out in 2030, gas will continue to account for a significant part of heating.

Figure 10: Final energy consumption by households analysed by selected heating technologies 2017-2030 [PJ]. Energy consumption by heat pumps includes ambient heat and electricity consumption. Gas comprises natural gas, gas works gas and bio-natural gas. District heating and fuel wood have been excluded.

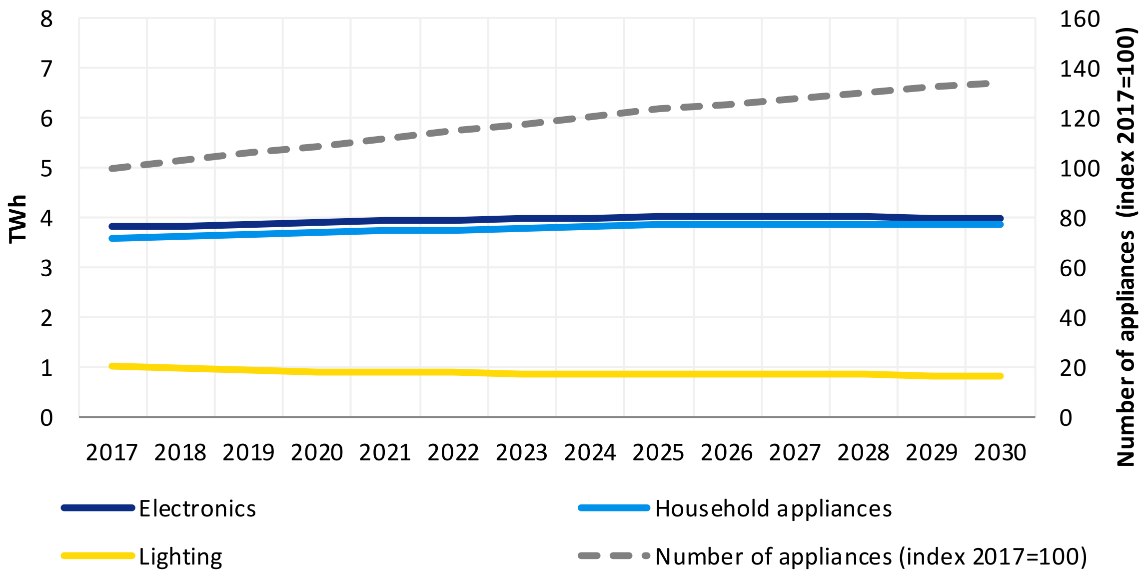


3.5 More, but also more efficient electrical appliances

Due to growing private consumption, people will buy more electrical appliances. Figure 11 illustrates that the number of electrical appliances is expected to increase by 2.3% annually. At the same time, the efficiency of appliances will improve due to the impact of the Ecodesign Directive (European Commission, 2009) and more efficient appliances are preferred by consumers following the Energy Labelling Directive (European Commission, 2017a). The projections are also conditional on an expectation that more products will be covered by these regulations. With this background, electricity consumption for appliances is expected to remain almost stable at around 31 PJ (8.7 TWh).

The projections show that there will be slightly increasing electricity consumption for more, but also more efficient, electrical appliances. Efficiency improvements of electrical appliances depend on EU standards for ecodesign and energy labelling of products.

Figure 11: Number of electrical appliances [Index] and developments in electricity consumption by use: electronic equipment, electrical appliances and lighting 2017-2030 [TWh].



3.6 Sensitivities and methodological considerations

Expectations regarding households' choice of heating technology are sensitive to fuel prices as well as consumer prices of electricity and district heating. Moreover, assumptions about technology costs for individual heating technologies have a significant impact. The Danish Energy Agency's basis for its expectations is described in the Danish Energy Agency Technology Catalogue for individual heating systems (Danish Energy Agency, 2019i).

Possible consequences of selected sensitivities for the key results of the projections are described in Chapter 8.

4 Energy consumption in industry and services

4.1 Main points

- Final energy consumption by industry and services will increase by 1.4% annually up to 2030. The increase primarily depends on increasing electricity consumption by large data centres and the end of the energy savings pools in 2024.

- More than 3/4 of fossil fuel consumption by industry and services will be used for medium- and high-temperature process heat in 2030. About 1/3 of oil consumption will be for internal transport purposes such as tractors, fishing boats and construction machines.

- Renewable energy consumption by industry and services will increase by 5.5% per year to amount to 13% of final energy consumption by industry and services in 2030.

- Consumption of electricity by industry and services will increase by about 3% annually, of which electricity consumption by large data centres will account for 80%.

- Use of heat pumps by industry and services will increase for both space heating and process heat. Consumption of electricity and ambient heat for heat pumps will increase from 2% of final energy consumption by industry and services in 2017 to around 5% in 2030.

- Energy intensity for industry and services (without data centres) will fall up to 2030, but the rate of reduction will halve from 2025 when the energy savings pools end in 2024.

Photo 1: Industry in Esbjerg. Process-related emissions from industry are expected to constitute a growing percentage of total emissions from industry and services (Text box 2, page 64).

4.2 The overall picture

In 2017, final energy consumption by industry and services was 34% of the total final energy consumption, and this is expected to rise to 38% in 2030. Figure 13 illustrates that changes can be divided into two periods. From 2017 to 2020 energy consumption by industry and services will increase by 0.9% annually, while from 2021 to 2030 it is expected to increase by 1.5% annually, corresponding to 1.4% per year on average from 2017-2030.

The increase in energy consumption by industry and services depends on increasing electricity demand for large data centres. There is significant uncertainty linked to the projections of electricity consumption by data centres (COWI A/S for the Danish Energy Agency, 2018). Energy consumption without data centres will increase by 0.6% annually.

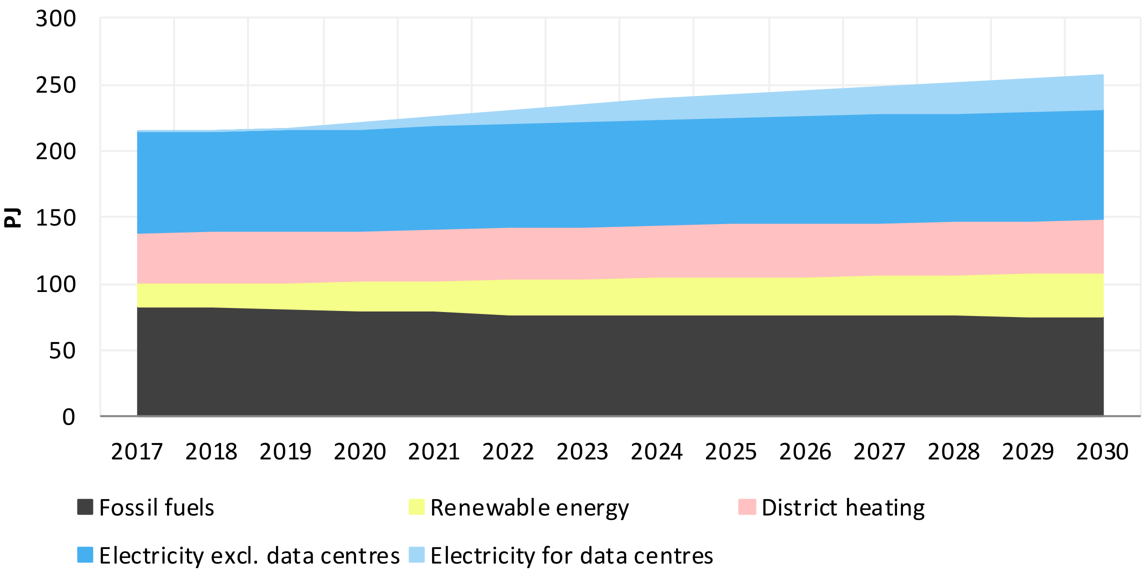
Total electricity consumption by industry and services will increase from 76 PJ in 2017 to 108 PJ in 2030, corresponding to an annual increase rate of 2.8%. 80% of this increase depends on increasing electricity demand for large data centres.

From 2017 to 2030, final consumption of fossil fuels by industry and services will fall from 83 PJ to 75 PJ, which means that the fossil fuels share of final energy consumption by industry and services will fall from 39% to 29%. About 3/4 of the consumption of fossil fuels by industry and services is used for medium- and high-temperature process heat. Consumption of renewable energy will increase from 8% of total final energy consumption by industry and services in 2017 to 13% in 2030, corresponding to an increase rate of 5.5% annually. This trend is due in particular to an increase in consumption of renewable energy gas and heat pumps.

The energy efficiency of industry and services is expected to continue to increase up to 2030, but the rate of increase will halve from 2025 because the energy savings pools only apply until 2024.

The projections show that energy consumption by industry and services will increase by 1.4% annually up to 2030 due to increasing electricity consumption by data centres and declining energy-efficiency improvements after 2024. The percentage of fossil fuels in final energy consumption by industry and services will fall to 29% in 2030.

Figure 12: Final energy consumption by industry and services by type of energy 2017-2030 [PJ].



4.3 Fossil fuel consumption will drop slightly up to 2030

Figure 13 shows that final fossil fuel consumption by industry and services will fall by 1.2% annually up to 2024, and then fall by 0.3% annually. Consumption of coal, coke, petroleum coke and fossil waste is expected to rise, however, to about 1% per year, due to expected economic growth.

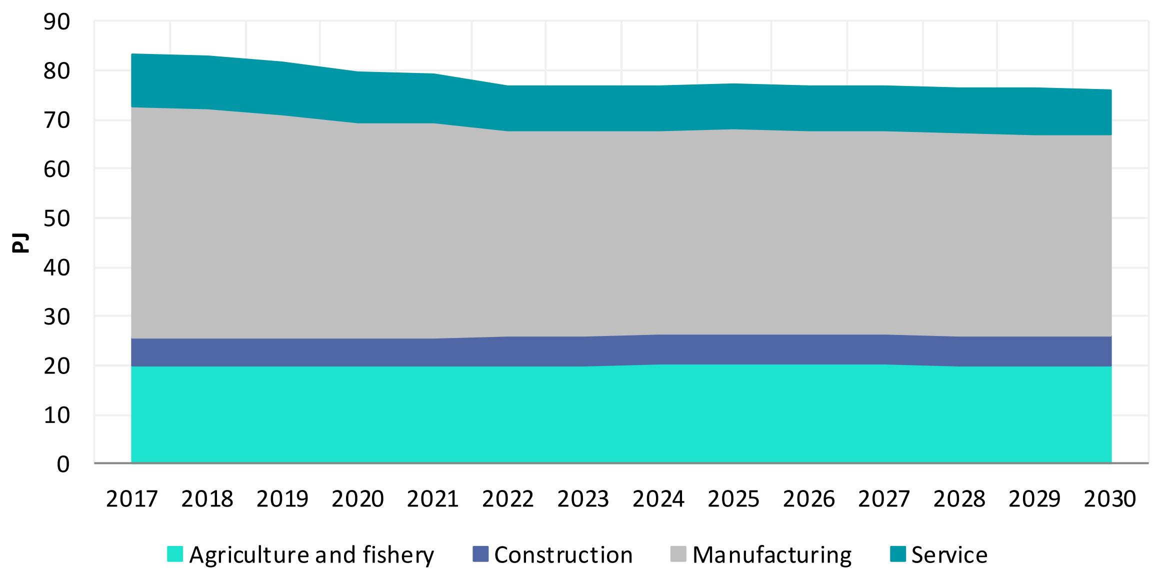
Consumption of fossil fuels in the service sector will fall from 11 PJ in 2017 to 9 PJ in 2024, corresponding to about 3% annually. From 2025, service sector fossil fuel consumption will level off.

Fossil fuel consumption by manufacturing industries will fall by 2% annually up to 2024, and then level off.

Consumption of fossil fuels in building and construction as well as agriculture, forestry and fishing is expected to remain unchanged in 2030 in relation to 2017.

> The projections show that consumption of fossil fuels by industry and services will fall up to 2024 and then level off. With regards to the service sector, natural gas consumption for space heating in particular will drop up to 2024.

Figure 13: Final consumption of fossil fuels by industry and services by sector 2017-2030 [PJ].



4.4 Fossil fuels primarily for medium and high-temperature process heat

Figure 14 shows that consumption of fossil fuels by industry and services in 2030 will be for internal transport, process heat and space heating. Internal transport includes commercial transport by vehicles and machinery such as construction machines, tractors, combine harvesters, fishing boats and trucks. Energy consumption for other commercial transport, such as vans, is included in energy consumption by the transport sector (Chapter 5).

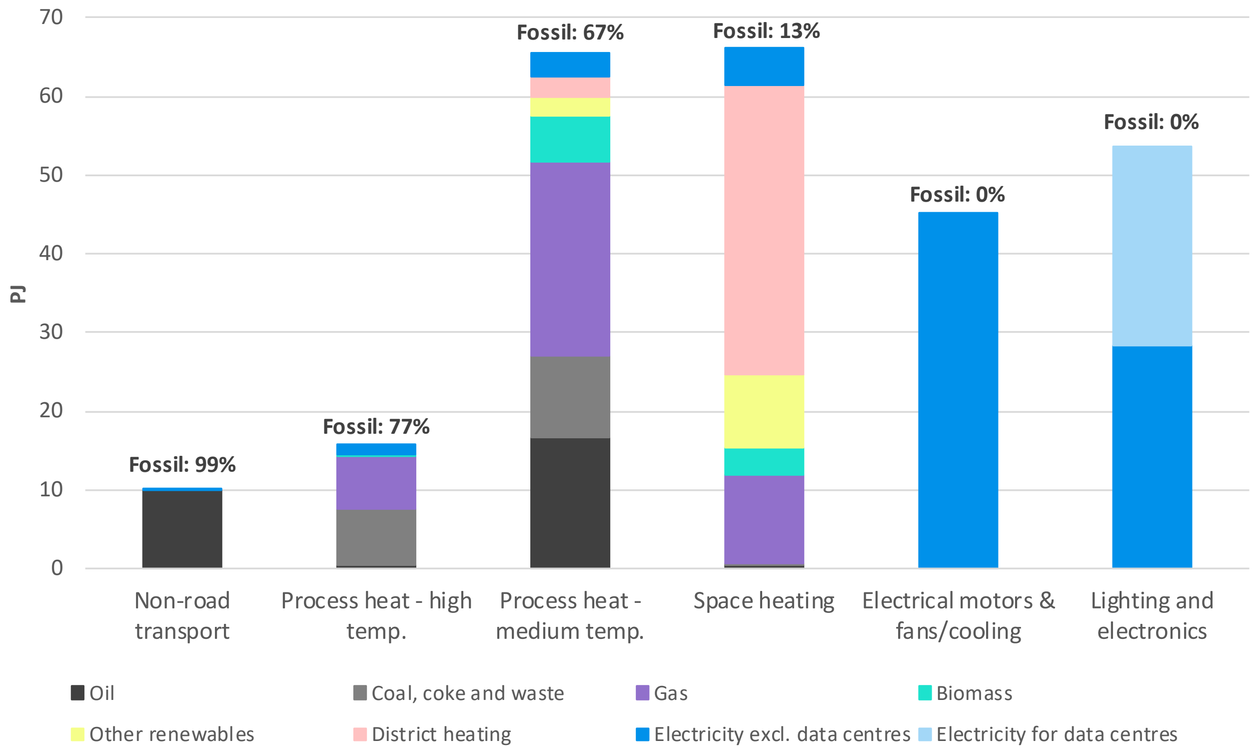
In 2030, more than 50% of consumption of fossil fuels by industry and services is expected to be used for medium-temperature process heat (less than 150 °C), while about 25% will be used for high-temperature process heat (more than 150 °C).

Around 2/3 of energy consumption for high-temperature process heat is direct firing, especially with coal, coke, petroleum coke and gas, used for example in the production of cement and tiles.

Fossil fuels are expected to account for 67% of energy consumption for medium-temperature process heat, 77% of energy consumption for high-temperature process heat (more than 150 °C) and 13% of energy consumption for space heating.

The projections show that, in 2030, more than 50% of consumption of fossil fuels by industry and services is expected to be used for medium-temperature process heat (less than 150 °C), while about 25% will be used for high-temperature process heat (more than 150 °C).

Figure 14: Industry and services' consumption of different types of energy by use in 2030 [PJ] and share of fossil fuels [%]. Coal includes coal, coke, petroleum coke and fossil waste. Gas comprises mains gas that includes both natural gas and bio-natural gas. The fossil share does not include fossil fuels used for electricity and district heating production.



4.5 Use of heat pumps will increase for both space heating and process heat.

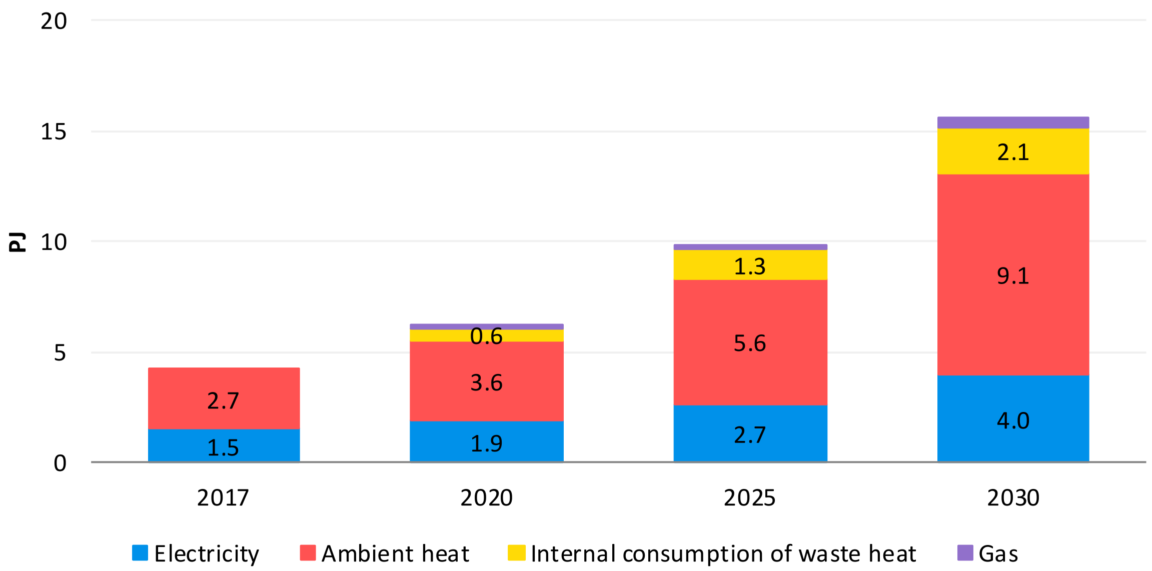
Use of heat pumps for space heating will increase, and use of heat pumps for industrial processes will also increase. By utilising internal waste heat from processes, heat pumps can provide higher temperatures with high efficiency, and this encourages increasing use for process purposes.

Figure 15 shows that electricity consumption by industry and services for heat pumps is expected to increase from 1.5 PJ in 2017 to 4 PJ in 2030, corresponding to a 7.6% annual increase.

Consumption of electricity and ambient heat for heat pumps is expected to increase from 2% of final energy consumption by industry and services in 2017 to 5% in 2030.

The projections show that industry and services is expected to invest in heat pumps used for both space heating and process heat. Consumption of electricity and ambient heat for heat pumps will account for 5% of final energy consumption by industry and services in 2030.

Figure 15: Industry and services energy consumption for heat pumps [PJ].



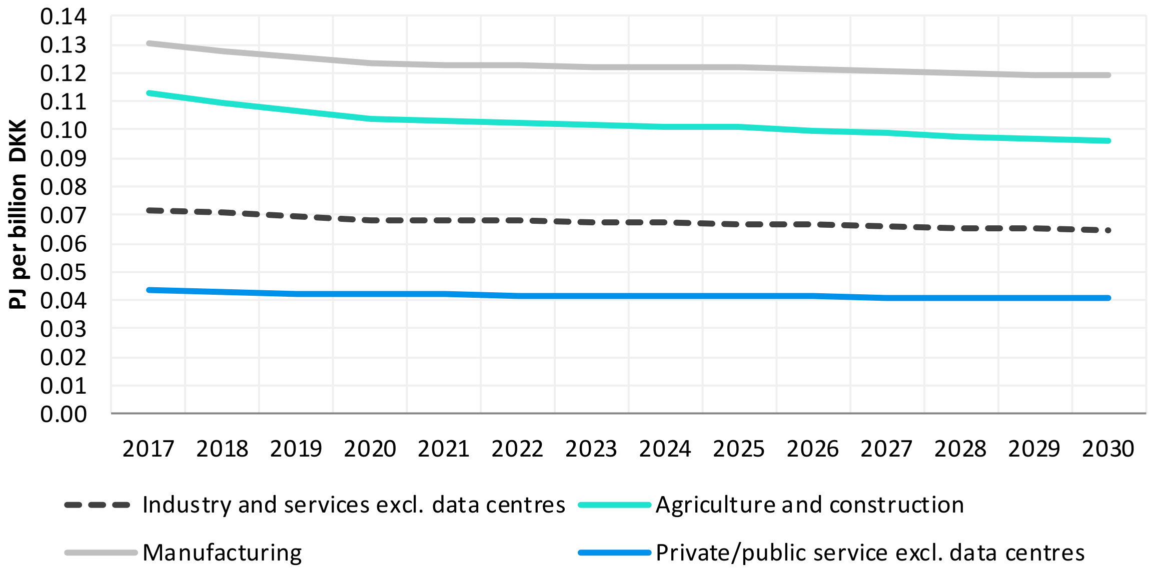
4.6 Energy intensity reduced further, but to a lesser extent from 2025

Energy efficiency in industry and services is reflected in energy intensity, which expresses energy consumption in relation to the production value. Falling energy intensity thus indicates increasing economic energy efficiency. The calculation of energy intensity is without data centres, as so far there is no statistical basis for assessing the production value of data centres.[5]

Figure 16 shows that energy intensity will fall up to 2030. Total energy intensity for industry and services will fall by around 1% annually up to 2024. From 2025 the drop in energy intensity will halve to 0.5% annually.

The projections show that energy intensity in industry and services will fall up to 2030, but the annual rate of reduction will halve from 2025 in the absence of new measures.

Figure 16: Energy intensity in industry and services by industry 2017-2030 [PJ/DKK bn.].



4.7 Sensitivities and methodological considerations

The projection of energy consumption by industry and services is sensitive to economic growth, and this is included as an overall exogenous assumption.

The projections are also sensitive to assumptions about by the demand for electricity from data centres, as well as to assumptions about the effect of the energy saving pool up to 2024. Technology choices and fuel use primarily depend on assumptions regarding technology costs, fuel prices and the carbon price.

Possible consequences of significant sensitivities for key results are described in Chapter 8.

[5] Sea transport, the utilities sector and energy production industries such as refineries have also been excluded. Production values and energy consumption from these are not included in this statement of energy intensities.

5 Energy consumption in transportation

5.1 Main points

- Final energy consumption by the transport sector will increase by 0.2% annually up to 2030.
- The share of fossil fuels in energy consumption by the transport sector will fall from 95% in 2017 to 92% in 2030.
- The renewables share in the transport sector (RES-T) will increase to 19% in 2030 based on the calculation method in the Renewable Energy Directive.
- Sales of electrified vehicles are expected to increase steadily and will account for 22% of total sales of new vehicles and 9% of the total number of passenger cars and vans on the road in 2030. The share of electrified vehicles in sales of new vehicles up to 2030 is subject to significant uncertainty.
- Electricity consumption by the transport sector will increase by about 13% annually up to 2030. Electricity consumption by road transport will correspond to electricity consumption by rail transport in 2030.

5.2 The overall picture

Final energy consumption by the transport sector was 218 PJ in 2017, corresponding to 34% of total final energy consumption. Up to 2030, final energy consumption by the transport sector is expected to increase by 0.2% annually and reach 223 PJ, which will correspond to 33% of total final energy consumption.

Up to the financial crisis in 2008, energy consumption by the transport sector was increasing steadily. The financial crisis and EU requirements for energy efficiency of vehicles resulted in a fall in energy consumption from 2008 to 2013, after which energy consumption rose again, primarily within aviation and road transport. For road transport, this was due in particular to increased road traffic volume and an associated increase in the number of vehicles, particularly small petrol cars and mid-range diesel cars.

Energy consumption by road transport is expected to increase by 0.1% annually up to 2030. The increase in energy consumption is less than the increase in road traffic volume. This is due to improvements in vehicle's energy efficiency as a result of technological developments, including electrified vehicles as well as EU requirements for manufacturers of passenger cars, vans and trucks.

Figure 17 shows that road transport will account for 74% of energy consumption by the transport sector in 2030, of which passenger cars and vans will account for 47 percentage points. Energy consumption by the aviation sector is expected to increase by 0.6% annually, and will account for

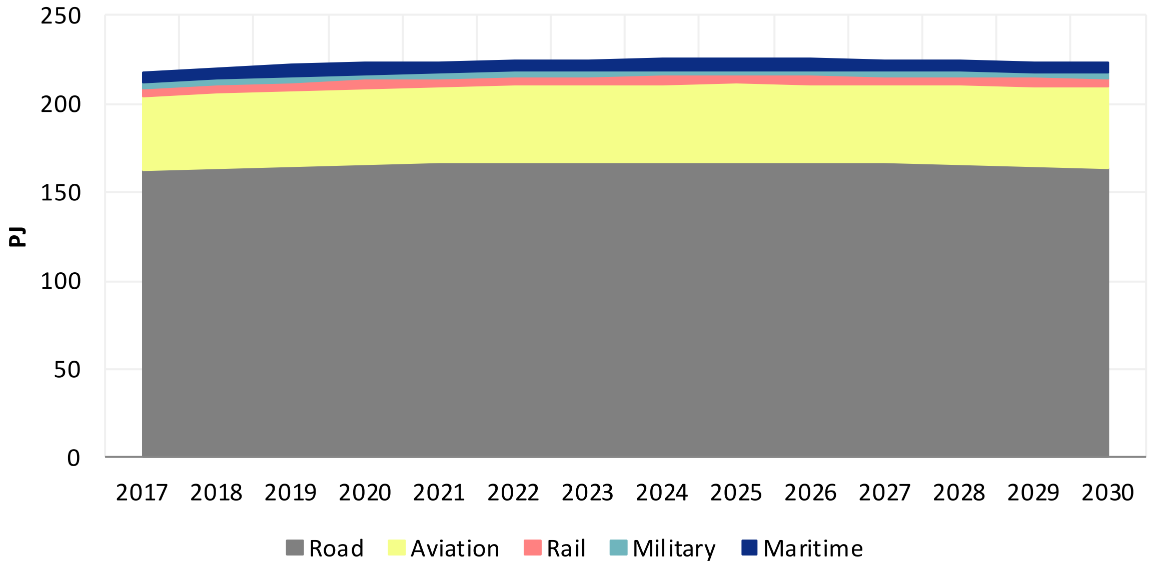
20% of energy consumption by the transport sector in 2030. This increase is due to a 35% increase in air traffic, whereas energy efficiency will improve by 26%.

The share of fossil fuels in energy consumption by the transport sector will fall from 95% in 2017 to 92% in 2030. The renewables share in the transport sector (RES-T) will, however, increase to 19% in 2030 based on the calculation method in the Renewable Energy Directive which reflects the value of a reduced conversion loss from using electricity based on renewable energy for transport (see glossary).

The renewables share increase is due in particular to an increased consumption of electricity produced from renewable energy sources (Chapter 6.3). In 2030, the renewables share of electricity consumption by the transport sector will correspond to the consumption of first generation biofuels.

The projections show that road transport will account for three-quarters of energy consumption by the transport sector. Electricity consumption by the transport sector will increase by 13% annually. The share of fossil fuels in energy consumption by the transport sector will fall to 92% in 2030. The renewables share in the transport sector (RES-T) will increase to 19% in 2030.

Figure 17: Final energy consumption by the transport sector by use 2017-2030 [PJ].



5.3 Electricity consumption by the transport sector is increasing

Figure 18 shows that electricity consumption by the transport sector will increase to 7.5 PJ in 2030, corresponding to an annual increase of 13%.

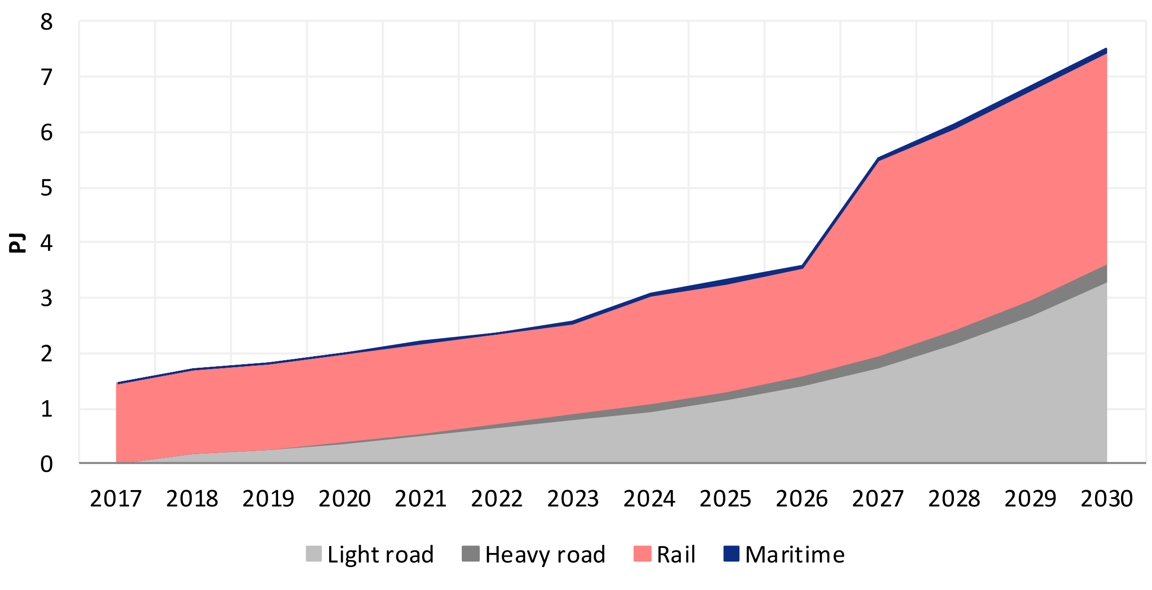
In 2030, light road transport (passenger cars and vans) and rail transport will account for 44% and 51% of electricity consumption by the transport sector, respectively.

A major increase in electricity consumption by rail transport in 2027 is based on expectations for a launch of new rolling stock and that the electrification of the link between Fredericia and Aalborg will be finished in 2026.

In addition, there will be less electricity consumption in heavy-duty transport (less consumption by trucks and buses, primarily intercity buses) and limited electricity consumption in maritime transport.

> The projections show that electricity consumption by the transport sector will increase by 13% annually. In 2030, electricity consumption by road transport is expected to correspond to electricity consumption by rail transport.

Figure 18: Electricity consumption by the transport sector by area of use 2017-2030 [PJ].



5.4 More electrified vehicles sold, making the share of total fleet 9% in 2030

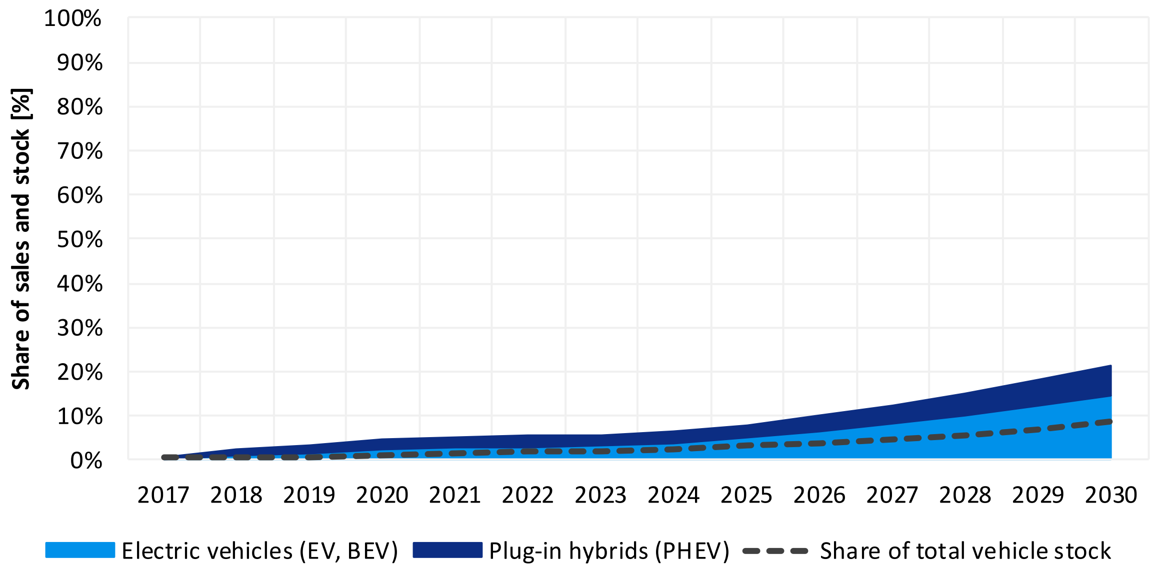
Figure 19 reflects the expectation that electrified passenger cars and vans will constitute an increasing share of sales of new vehicles up to 2030. This is based on expectations of technological developments and falling technology costs. On this basis, electrified vehicles are expected to account for 22% of total sales of new vehicles in 2030, in the absence of new measures. Sales of hydrogen vehicles are expected to be very limited.

The number of electrified passenger cars and vans will increase to around 300,000 in 2030, and electrified passenger cars and vans will make up almost 9% of the total fleet in 2030.

Electrified vehicles are expanding into the global car market. However, this technology is still under development. This entails a significant uncertainty about sales and the total number of electrified vehicles up to 2030.

The projections show that electric vehicles and plug-in hybrid vehicles, in the absence of new measures, are expected to account for 22% of sales and almost 9% of the total number of passenger cars and vans on the road in 2030. This corresponds to approximately 300,000 electrified passenger cars and vans in 2030.

Figure 19: Electrified vehicles' share of sales of new vehicles and share of total number of passenger cars and vans on the road 2017-2030 [%].



5.5 92% of energy consumption by transport will be fossil in 2030

Measured in relation to final energy consumption, the share of fossil fuels in the transport sector will fall from 95% in 2017 to 92% in 2030. This is due to a combination of electrification of the rail and road transport sectors as well as improved energy efficiency for conventional vehicles. Fossil fuel consumption by road transport is expected to amount to 73% of total fossil fuel consumption by the transport sector in the absence of any new measures.

Figure 20 shows that the renewables share increasingly consists of electricity produced from renewable energy sources. In 2030, the renewables share of electricity consumption by the transport sector will correspond to the consumption of first generation biofuels, whereas consumption of second generation biofuels will constitute a smaller share.

Certain multiplication factors reflecting the value of a reduced conversion loss when using electricity must be used to calculate the renewables share in the transport sector according to the method in the Renewable Energy Directive (RES-T) (see glossary for definition of RES-T). RES-T is expected to be 9% in 2020 and will increase to 19% in 2030.

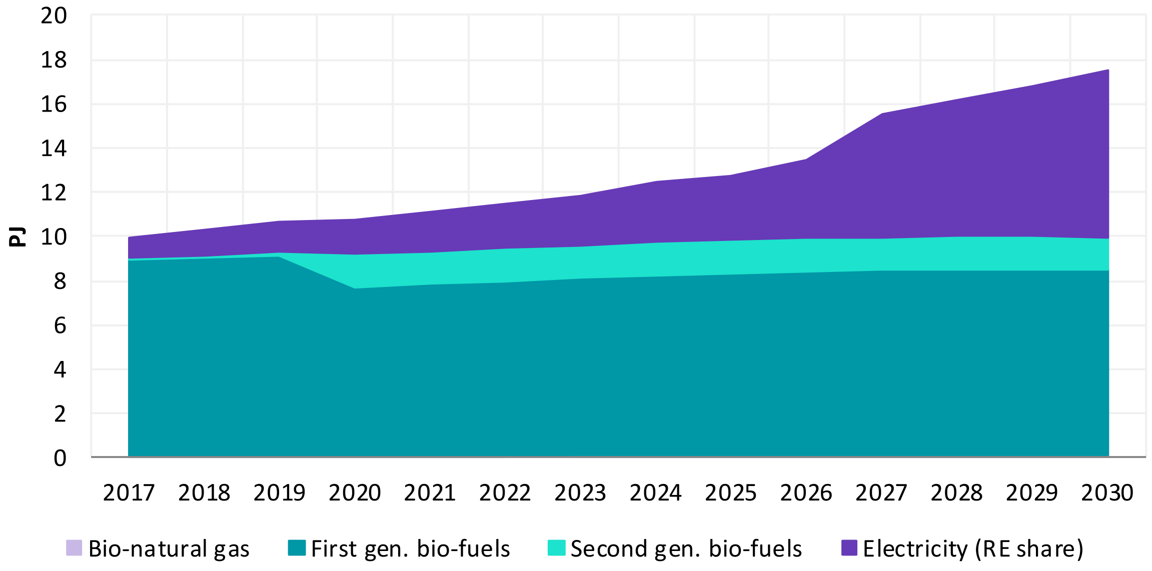
Consumption of biofuels, except for bio-natural gas, is expected to increase to 9.8 PJ in 2030, corresponding to 4% of energy consumption by the transport sector. Blending of biofuels with petrol and diesel fuel for road transport will not increase after 2020 in the absence of any new measures.

Consumption of gas which includes a growing share of bio-natural gas will increase, but bio-natural gas is expected to constitute a very limited share of renewable energy consumption in transport.

Fuel consumption for aviation is expected to be 100% based on fossil fuels throughout the period in the absence of new measures.

The projections show that the share of renewable energy in the transport sector is increasing, although renewable energy will continue to constitute a minor share of energy consumption by the transport sector. Renewable energy consumption by the transport sector will increasingly be influenced by the renewables share of electricity consumption which, in 2030, will correspond to consumption of first generation biofuels. Fuel consumption for aviation is expected to be 100% based on fossil fuels throughout the period. The renewables share in the transport sector (RES-T) calculated on the basis of the method in the Renewable Energy Directive is expected to amount to 9% in 2020 and will increase to 19% in 2030.

Figure 20: Renewable energy consumption by the transport sector 2017-2030 [PJ].



5.6 Sensitivities and methodological considerations

The projections are based on the expectation of a continued increase in demand for road transport. Moreover, the projection includes an expectation that technological developments will lead to cheaper batteries and thereby cheaper electric vehicles and plug-in hybrid vehicles. The project also assumes that the relaxation of vehicle registration tax for electric vehicles will be phased out in 2023.

The projection also includes the effect of new EU requirements for emissions from newly registered vehicles that is expected to lead to increased energy efficiency of conventional vehicles. So far, there has been no decision on the effect of driverless cars and car-share schemes, for example.

Road transport projections are particularly sensitive to assumptions about road transport volume, the efficiency of vehicles as well as to assumptions about future sales of petrol and diesel vehicles and electrified vehicles. In addition, there is methodological uncertainty associated with the calculation of the difference between standard figures for fuel consumption by new vehicles and actual energy consumption when travelling on the road.

The projection does not include effects of any use of biofuel in aviation fuel.

Sensitivity analyses have been made on the phase-in rate for electrified vehicles and for biofuel blending in the aviation sector. Possible consequences of these sensitivities for overall key results are described in Chapter 1.

6 Production of electricity, district heating and renewable energy gas

6.1 Main points

- Developments in electricity and district heating supply up to 2030 will be characterised by an almost full conversion to renewable energy. This depends on an expected phase out of large-scale coal-fired and small-scale gas-fired CHP as well as continued deployment of offshore wind, onshore wind and solar PV.

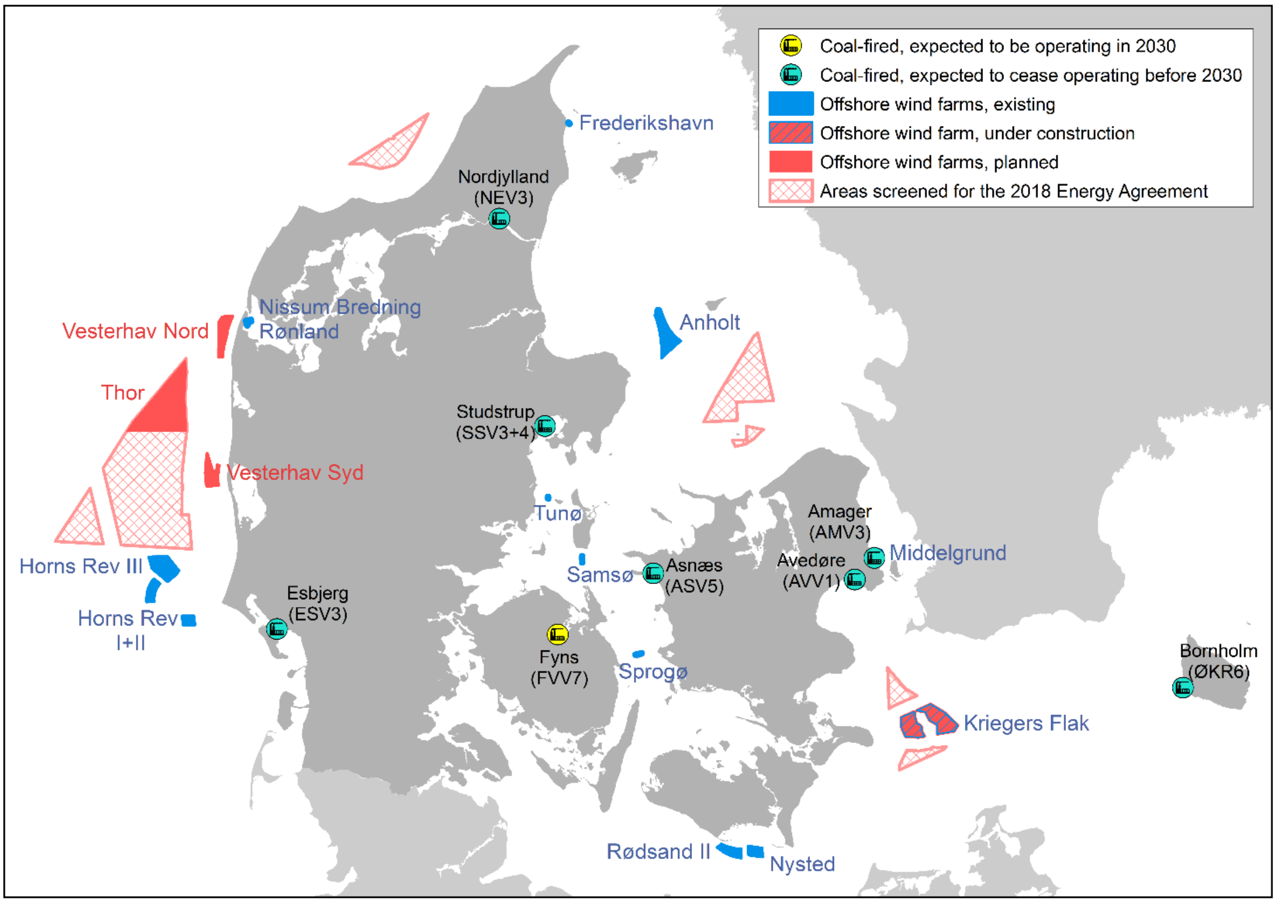
- The renewables share of electricity consumption (RES-E) will exceed 100% from 2028 and is expected to reach 109% in 2030. The increase in RES-E is contingent on expectations of deployment of wind power and solar PV in particular.

- The renewables share of district heating (RES-DH) will increase in particular up to 2023 and is expected to reach 80% in 2030. Heat production from large heat pumps and electric boilers will increase from 1% of the district heating consumption in 2017 to 11% in 2030.

- Coal consumption for production of electricity and district heating will drop from 85 PJ in 2017 to 7 PJ in 2030. This is contingent on expectations regarding discontinuation of operation or conversion to solid biofuels at specific coal-fired CHP plants. In the absence of any new measures, Fynsværket is the only coal-fired plant expected to be operational in 2030. Natural gas consumption for production of electricity and district heating will drop from 38 PJ in 2017 to 8 PJ in 2030. This is contingent on declining gas-based CHP capacity and increased biogas blending in the grid.

- Production of renewable energy gas in the form of bio-natural gas, which is biogas upgraded through blending with natural gas in the grid, and decreasing consumption of gas from the grid mean that the share of bio-natural gas produced will increase in 2030 to 25% of total domestic consumption of gas.

Figure 21: Location of coal-fired electricity production plants and offshore wind turbines.



6.2 The overall picture

Figure 22 illustrates that developments in electricity and district heating supply up to 2030 will be characterised by almost full conversion to renewable energy. This depends on an expected phase out of large-scale coal-fired and small-scale gas-fired CHP as well as continued deployment of offshore wind, onshore wind and solar PV. Consumption of coal, natural gas and oil for production of electricity and district heating is expected to be reduced by 86% in 2030 compared with 2017.

The renewables share in electricity consumption (RES-E) will increase steadily from 64% in 2017 to more than 100% in 2028 and will reach 109% in 2030. A renewables share of more than 100% means that domestic production of renewable energy exceeds domestic consumption.

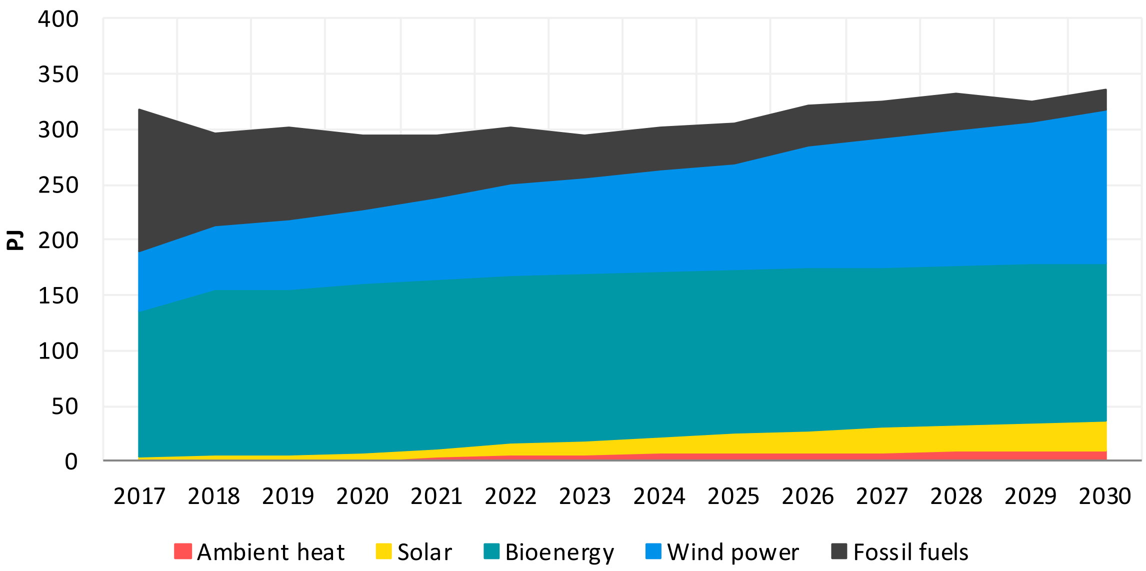
The renewables share in district heating consumption (RES-DH) will increase from 55% in 2017 to 76% in 2023 and will then slowly increase up to 80% in 2030. District heating supply will be characterised by conversion from coal and gas to biomass and heat pumps. RES-DH will not reach a higher level, particularly due to the consumption of waste for incineration in district heating production and the fossil (non-biodegradable) component in this. The fossil share of waste for incineration will cover around 10% of district heating consumption in 2030 in the absence of any new measures.

The increasing electricity production from wind power means that, in normal years, Denmark will be an ever larger net exporter of electricity from 2026 onwards. In the absence of any new measures, in 2030 net exports of electricity will constitute 12% of domestic electricity production, corresponding to 14% of electricity consumption (including grid losses).[6]

Increased production of renewable energy gas in the form of bio-natural gas, which is biogas upgraded through blending with natural gas in the grid, and decreasing consumption of mains gas also mean that the share of bio-natural gas production will increase from 5% in 2017 to 25% in 2030 in relation to the domestic consumption of gas.

The projections show that developments in electricity and district heating supply up to 2030 will be characterised by an almost full conversion to renewable energy. This depends on an expected phase out of large-scale coal-fired and small-scale gas-fired CHP as well as continued deployment of offshore wind, onshore wind and solar PV, whereas the consumption of bioenergy will increase to a lesser extent. The renewables share in electricity consumption (RES-E) will reach 109% in 2030, the renewables share in district heating consumption (RES-DH) will reach 80% in 2030, while the share of bio-natural gas production will increase to 25% in 2030 compared with the domestic consumption of gas.

Figure 22: Consumption of energy by the electricity and district heating sector, by type of energy 2017-2030 [PJ].



[6] Calculations are based on normal years, and fluctuations can be expected in individual statistical years.

6.3 The renewables share in electricity consumption (RES-E) will exceed 100% in 2028

Figure 23 shows that the renewables share in electricity consumption (RES-E) will increase steadily and is expected to exceed 100% from 2028 and reach 109% in 2030. This development is contingent on new offshore wind, updated expectations regarding the deployment of commercial solar PV (ground-mounted solar farms) and the expected replacement of older onshore wind turbines with fewer, more efficient turbines.

In the following, grid-connected capacity is stated as per 1 January of the year concerned.

Total installed capacity of offshore wind will increase from 1,300 MW in 2017 to 4,900 MW in 2030. This depends on the deployment of three new offshore wind farms of a total of 2,700 MW. From pre-feasibility studies, the average farm size for new offshore wind farms has been adjusted upwards from 800 MW, as decided in the Energy Agreement 2018 to 900 MW. In addition, deployment of 390 MW offshore wind is expected, possibly nearshore.

Total installed capacity of onshore wind will increase from 4,200 MW in 2017 to 5,300 MW in 2024, after which it will decrease to 4,800 MW in 2030. However, electricity production from onshore wind is expected to increase over the entire period, as new turbines are more efficient than older turbines. From 2019 to 2021, the capacity of onshore wind is expected to increase by 500 MW. Of this, three projects will be financed by the 2018 technology-neutral tendering round, whereas other projects are expected to be realised through future technology-neutral tendering rounds or financed on market terms through a PPA. From 2022, deployment of onshore wind is expected to be around 225 MW annually up to 2030. In addition, deployment of 135 MW capacity of test turbines is expected.[7] The number of onshore wind turbines is expected to be reduced from 4,200 in 2017 to around 1,500 turbines in 2030.

Total solar PV capacity will increase from 900 MW in 2017 to 4,900 MW in 2030. This depends on an expected deployment of 3,750 MW of commercial ground-mounted solar farms. The expectation of ground-mounted solar farms is based on an updated assessment of data from municipalities, project developers and grid companies.

From feasibility assessments for households and other industries, capacity is expected to increase by a further 365 MW of building-integrated (including roof-top solar) installations up to 2030.

Background appendices to DECO19 (Danish Energy Agency, 2019a) describe in more detail the projections of deployment of onshore wind and solar PV. The basis for the projections is primarily expectations of developments in electricity prices (Chapter 6.5), falling technology costs (Danish Energy Agency, 2019i) and levels of prices achieved in the 2018 technology-neutral tendering round (Danish Energy Agency, 2019f), as well increasing interest from businesses to meet voluntary renewable energy targets through guarantees of origin in combination with funding opportunities in the form of technology-neutral tendering rounds and/or PPAs (Textbox 1). There seems to be considerable uncertainty associated with assumptions regarding market-based

[7] It is possible to achieve a price supplement for electricity production on test turbines at and outside the Høvsøre and Østerild national test centres. Although the primary purpose of test turbines is testing and development andnot electricity production, nevertheless the test turbines will contribute to the electricity supply to some degree.

financing for onshore wind and solar PV after the end of technology-neutral tendering rounds as well as assumptions regarding the decommissioning of older wind turbines.

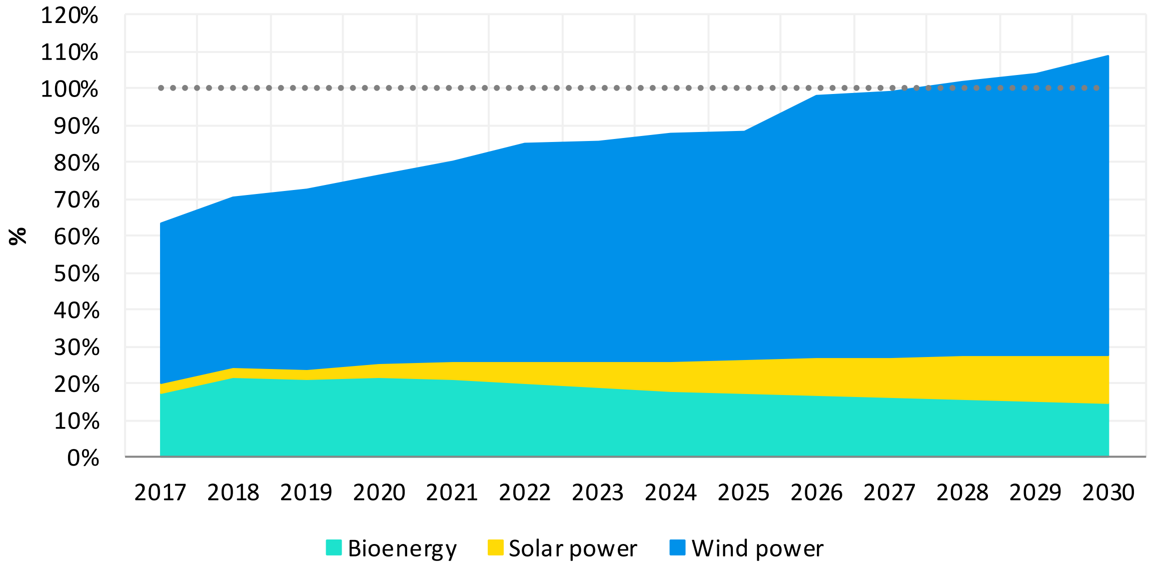
Textbox 1: "Power Purchase Agreement" (PPA) can contribute to financing renewable energy deployment.

A PPA (Power Purchase Agreement) is a direct agreement between the investor/producer and consumer on trade in a specific production of electricity. For example, a PPA may help ensure a major consumer a guarantee of origin for purchases of renewable energy to cover its electricity consumption. A PPA may contribute to financing new capacity on market terms. Businesses seem to increasingly appreciate the value of voluntary renewable energy targets. Facebook's target of being 100% reliant on renewable energy in 2020 is an example of this (Facebook, 2019).

On behalf of the Danish Energy Agency, K2 Management A/S has analysed the potential for commercial PPA agreements in Denmark (K2 Management on behalf of the Danish Energy Agency, 2019). The analysis presents several scenarios for promoting PPAs. In the central scenario ("realistic growth" scenario), the analysis suggests that PPAs could form the basis for 29% of total electricity consumption by industry and services in 2040. Such an expectation is associated with considerable uncertainty.

The projections show that the renewables share in electricity consumption (RES-E) will increase steadily and is expected to exceed 100% from 2028 and reach 109% in 2030. This depends on the deployment of offshore wind, onshore wind and commercial solar PV. Expectations regarding the deployment of onshore wind and commercial solar PV are particularly sensitive to developments in technology costs and the importance of major consumers' voluntary renewable energy targets and financing terms, including bilateral electricity trade agreements (PPAs).

Figure 23: Renewables share in electricity consumption (RES-E) by wind power, solar PV, bioenergy and hydropower 2017-2030 [%]. Hydropower is very small and has been included in solar PV.



6.4 Increasing electricity production from renewable energy will be exported from 2026

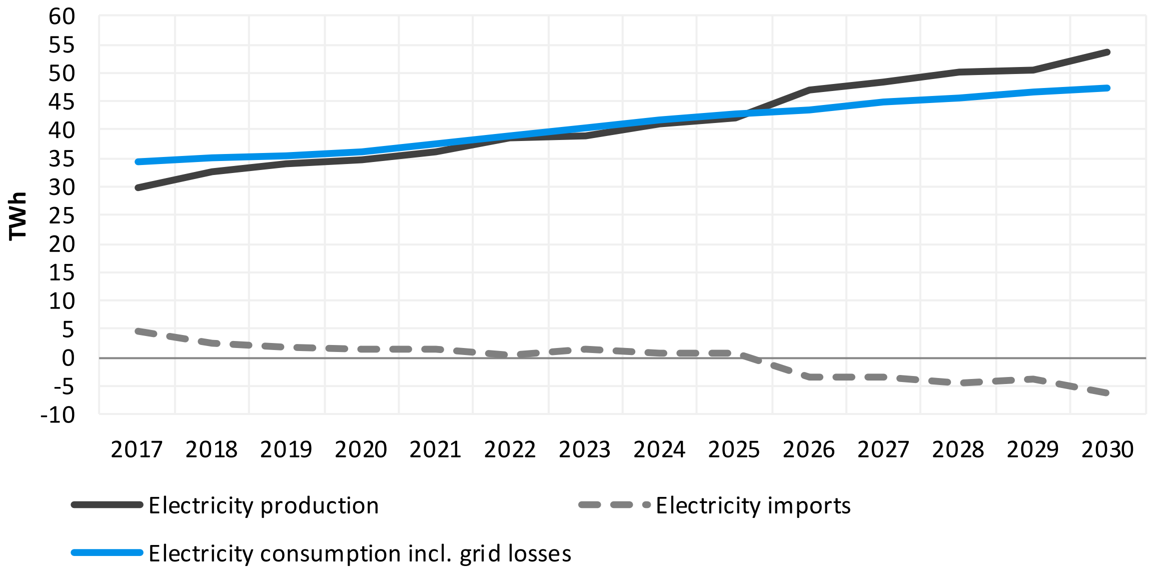
Figure 24 shows that electricity consumption, including grid losses, is expected to increase from 34 TWh in 2017 to 50 TWh in 2030, corresponding to an annual increase of 3%.

The increasing electricity consumption is followed by a relatively larger increase in domestic electricity consumption, which will increase from 30 TWh in 2017 to 54 TWh in 2030, corresponding to an annual increase of 4.7%. This increase depends on the deployment of wind power and solar PV, and on Denmark's potential to sell electricity on high-price markets in the Netherlands (via Cobra Cable), the United Kingdom (via Viking Link) and Germany (via the East Coast and West Coast Links).

Denmark is expected to be an increasingly larger net exporter of electricity from 2026. In the absence of any new measures, in 2030 net exports of electricity are expected to constitute 12% of electricity production, corresponding to 14% of electricity consumption (including grid losses).

The projections show that increasing electricity production from wind power and solar PV is expected to result in systematically increasing net exports of electricity in the absence of any new measures. Net exports are expected to amount to 14% of electricity consumption, including grid losses, in 2030 in the absence of any new measures.

Figure 24: Electricity consumption, including transmission and distribution losses, electricity production and electricity imports 2017-2030 (TWh).



6.5 More renewable energy abroad, more interconnectors and stable electricity prices

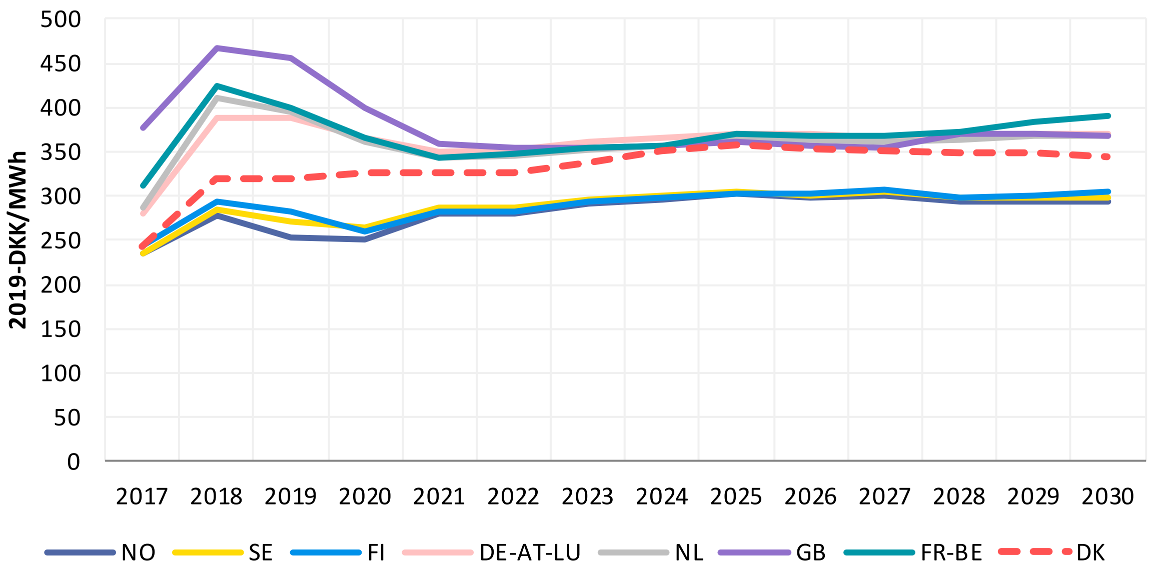
The composition of the electricity production capacity in Europe up to 2030 is marked by expectations of more renewable energy and more interconnectors as described in the background appendices to DECO19 (Danish Energy Agency, 2019a). The consequence of this development is expected to be a reduced difference in electricity prices and greater price stability between connected market areas.

Figure 25 shows that, on this basis, up to 2021, Denmark's price zone converges toward just below a continental north-west European price range, while the other Nordic countries are expected to group together at a lower price range.

Prices for all the years are model results. The Danish Energy Agency uses statistical prices for 2017-2018 and forward prices for 2019-2020. The resulting projection of electricity prices, including technology-weighted electricity prices and hourly electricity prices are stated in the background appendices to DECO19 (Danish Energy Agency, 2019a).

The projections show that Denmark's electricity price zone converges toward just below a continental north-west European price range, while the other Nordic countries are expected to group together at a lower price range.

Figure 25: Electricity spot market prices for Denmark and selected price-setting markets 2017-2030 [2019 DKK/MWh]. Prices for all the years are model results. The Danish Energy Agency uses statistical prices and forward prices for 2017-2020. NO: Norway, SE: Sweden, FI: Finland, DE-AT-LU: Germany, Austria, Luxembourg, NL: The Netherlands, GB: Great Britain, FR-BE: Belgium, DK: Denmark.

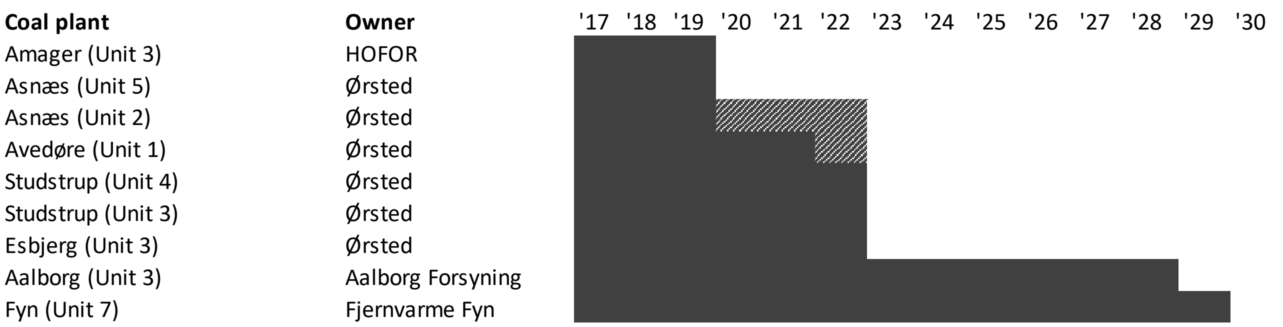


6.6 Consumption of coal and gas will be reduced by 85% up to 2030

Figure 28 shows that the consumption of fossil fuels for electricity and district heating production will be reduced to 17 PJ in 2030, corresponding to a reduction of 85% compared with 2017. Coal consumption will be reduced to 7 PJ, corresponding to a reduction of 92%.

The reduction in coal consumption is linked to an expected date for decommissioning specific coal-fired power plant units. Figure 21 (page 46) illustrates the geographic location of coal plants, whereas Figure 26 illustrates the expected availability of coal plants during the projection period.

Figure 26: Availability of coal plants in the projection 2017-2030. Light grey shows that operation of the relevant plant is expected to be limited in the relevant period.



Ørsted A/S, which owns Asnæsværket, Studstrupværket, Esbjergværket and Avedøreværket, has announced that they will stop using coal from 2023. Projections reflect that coal operation at these plants can no longer be expected to be profitable due to increasing costs from 2023. Among other things, this is due to expectations of increasing carbon prices.

Aalborg Forsyning A/S, which owns Nordjyllandsværket, has announced that they will stop using coal from 2029. The projections reflect that transitioning to district heating supply based on other fuels is expected to be financially viable for society as well as for businesses from 2029.

Fjernvarme Fyn A/S, which owns Fynsværket, has not presented their final decision as to whether they will stop using coal. Projections reflect that operation of Fynsværket up to 2030 will still be financially profitable due to Fynsværket's production of process heat for horticultural industry.

Figure 27 shows that small-scale district heating plants in small and medium-sized urban areas are expected to replace gas-fired CHP with electric boilers and heat pumps, for example. Small plants' capacity for electricity consumption in 2030 is likely to correspond to their capacity for electricity consumption for heating. Moreover, development of medium-sized plants is characterised by declining gas-based electricity capacity and increasing capacity to meet electricity demand for heating. Projections of increases in small-scale CHP capacity are based on detailed profitability assessments of investment opportunities on current market terms in the individual district heating areas (Danish Energy Agency, 2019a). Figure 28 shows that the consumption of natural gas is expected to be reduced to 8 PJ in 2030, corresponding to a reduction of 80% compared with 2017.

The projections show that consumption of coal by the electricity and district heating supply sector will be reduced by 92%, whereas natural gas consumption will be reduced by 80% up to 2030.

Figure 27: Small-scale electricity production capacity (>0) and electricity consumption capacity for heat production (<0) in small and medium-sized urban areas 2017-2030 [MW electricity].

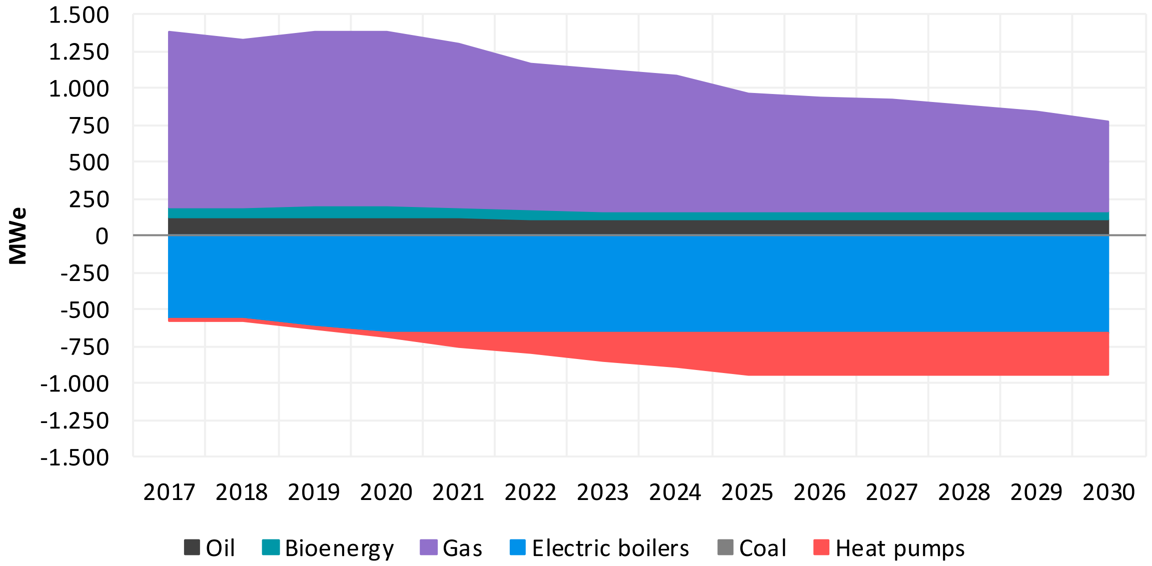
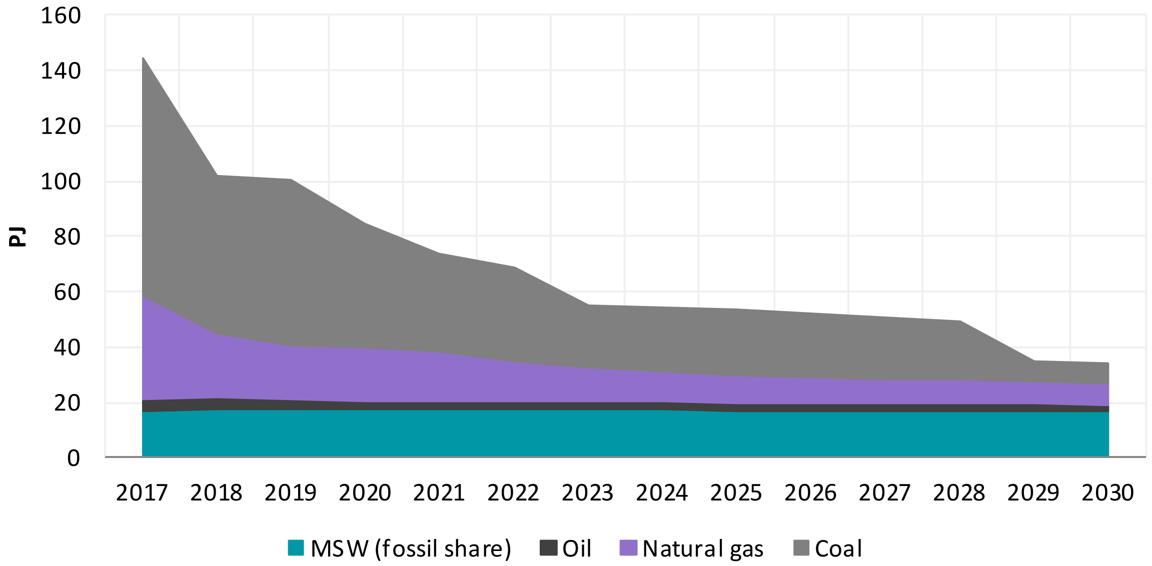


Figure 28: Consumption of fossil fuels in the electricity and district heating sector 2017-2030 [PJ].



6.7 The CHP share of electricity and heat production is falling steadily

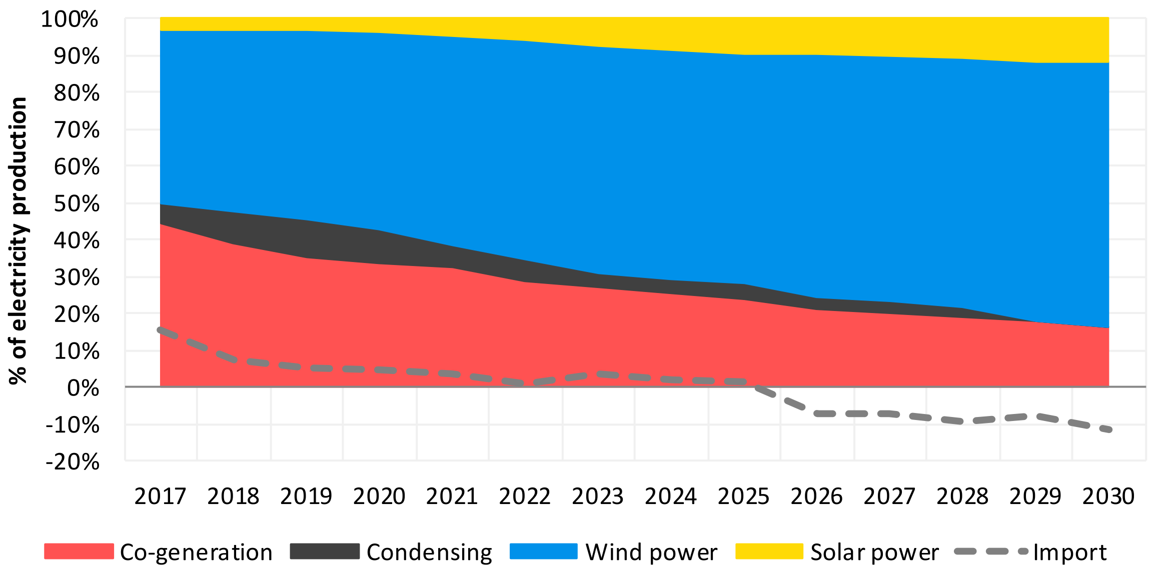
Figure 29 shows that the CHP share of electricity production, i.e. where heat is produced via electricity production, will fall steadily from 44% in 2017 to 17% in 2030.

The share of electricity production without production of heat (condensing operation) will be reduced as a result of decommissioning coal-fired power plant units and discontinuation of condensing operation at Fynsværket.

In 2030, net exports of electricity will constitute 12% of domestic electricity production in the absence of any new measures.

The projections show that the CHP share of electricity and heat production is falling. Very limited condensing operation is expected at CHP plants in 2030. This is contingent on decommissioning coal-fired power plant units and discontinuation of condensing operation at Fynsværket.

Figure 29: Domestic electricity production by type of production, and share of electricity imports in total electricity production [%].



6.8 The renewables share in district heating (RES-DH) will increase and then level off

Figure 30 shows that consumption of biomass will see an annual increase of almost 10% up to 2020, replacing consumption of coal and natural gas. This development reflects the effect of a transition to biomass at several CHP plants that has already been decided and is ongoing. Consumption of coal will therefore decrease by almost 30% annually up to 2020, after which it will decrease to a smaller extent by around 10% annually. Natural gas consumption will decrease steadily by around 10% annually throughout the period.

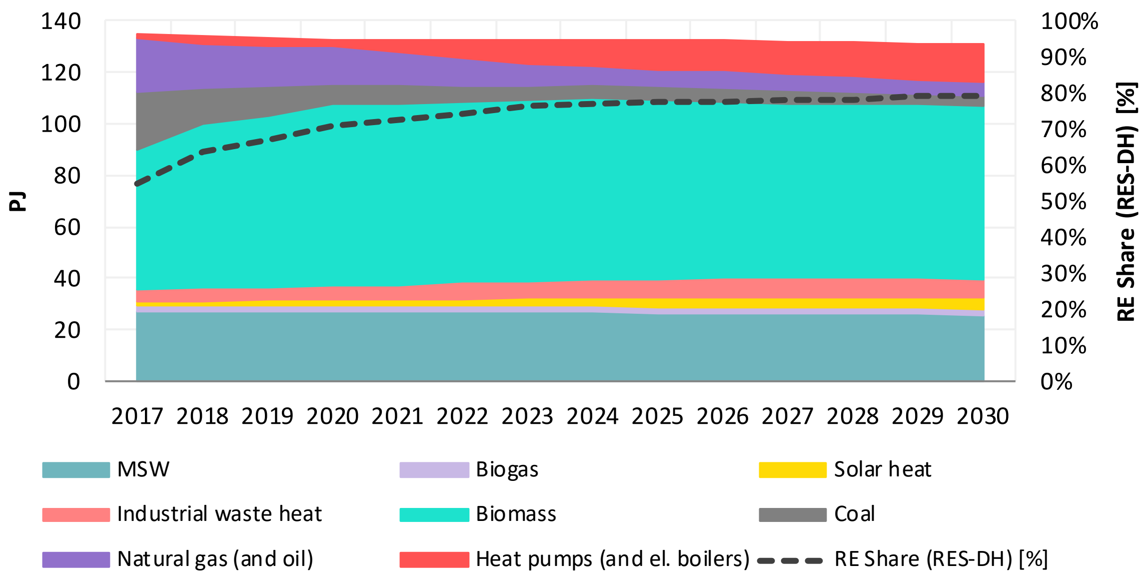
District heating production from heat pumps and electricity boilers will increase by 15% annually. Among other things, this is conditional on a reduction in the tax on electric heating and on phasing out the PSO tariff. Heat pumps and electric boilers are expected to account for around 10% of total district heating production in 2030.

Consumption of solar thermal energy will increase by around 10% annually, and consumption of industrial surplus heat will increase by 3% annually, while consumption of biogas and waste will be constant. Non-biodegradable waste is included in fossil fuels, and will account for around 10% of district heating production in 2030.

On this basis, the renewables share in district heating (RES-DH) is expected to increase from 55% in 2017 to 76% in 2023, and then increase slightly to almost 80% in 2030. RES-DH will not reach a higher level, particularly due to the consumption of waste in district heating production and the fossil (non-biodegradable) share of this.

The projections show that the renewables share in district heating (RES-DH) will increase to 76% up to 2023, and then increase slightly to almost 80% in 2030. Heat pumps and electric boilers are expected to account for 10% of total district heating production in 2030, while solar thermal heating is expected to account for 3%. The fossil share of waste for incineration will amount to 10% of district heating production in 2030.

Figure 30: District heating production by type of energy and renewables share in district heating 2017-2030 [PJ]. Heat pumps cover production from ambient heat and surplus heat. Surplus heat is without use of heat pumps.



6.9 Bio-natural gas will account for 25% of total consumption of mains gas in 2030.

Production of biogas to be upgraded by blending in the grid (bio-natural gas) is expected to increase up to 2023.[8]

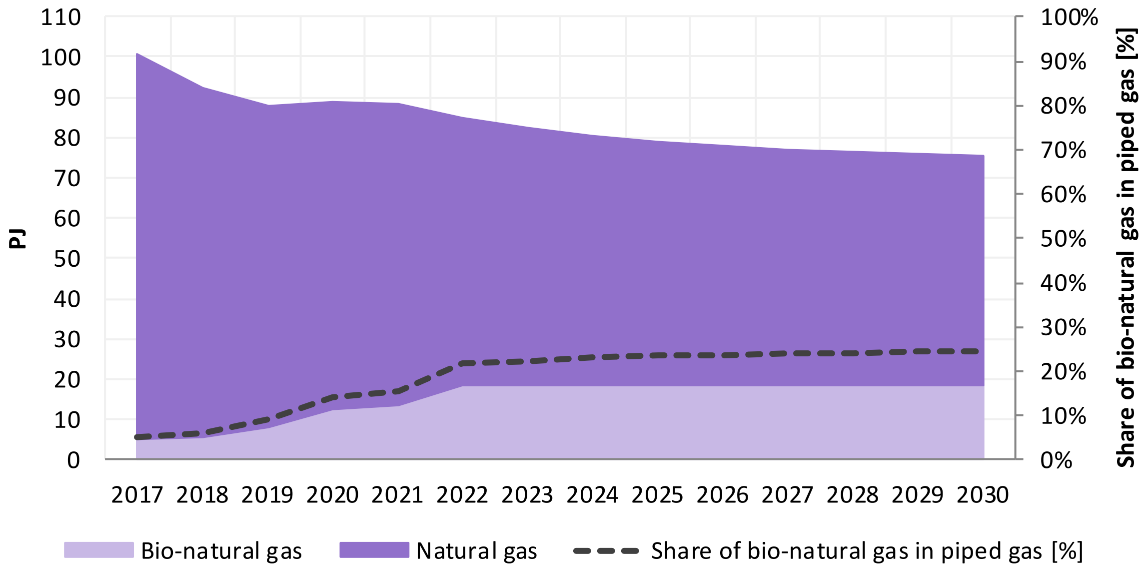
Production and consumption of biogas directly for electricity and heat production as well as for industrial processes are expected to be maintained at the current level.

Figure 31 shows that the production of bio-natural gas is expected quadruple to 18.5 PJ in 2023, after which production will level off. However, falling gas consumption will mean that the share of bio-natural gas relative to total consumption will continue to increase up to 2030. The share of bio-natural gas in relation to total consumption is expected to increase to 25% in 2030.

Background appendices to DECO19 (Danish Energy Agency, 2019a) describe in more detail the projections of biogas production broken down by use.

The projections show that increased production of bio-natural gas and decreasing consumption of gas from the grid mean that the share of bio-natural gas produced will increase to 25% in 2030 compared with the domestic consumption of gas.

Figure 31: Consumption of mains gas broken down by natural gas and bio-natural gas 2017-2030 [PJ], and the share of bio-natural gas in mains gas [%]. The calculation is based on bio-natural gas produced in relation to the domestic consumption of mains gas.



[8] Bio-natural gas is biogas that has been upgraded to meet the supply requirements for gas in the grid.

6.10 Sensitivities and methodological considerations

Projections of electricity and district heating supply as well as production of renewable energy gases are particularly sensitive to the following assumptions:

- Developments in electricity consumption, in particular uncertainty about electricity consumption by large data centres
- Developments in fuel prices and carbon prices.
- Domestic deployment of onshore wind, in particular the rate with which older wind turbines will be decommissioned and the availability of locations for new turbines
- Domestic deployment of commercial solar PV (ground-mounted solar farms)

Possible consequences of significant sensitivities for key results are described in Chapter 8.

Photo 2: Denmark is expected to be an ever larger net exporter of electricity from the mid-2020s.

7 Emissions of greenhouse gases

7.1 Main points

- Since 1990, annual greenhouse gas emissions have fallen from 70.8 million tonnes to 50.8 million tonnes CO2-eq. in 2017, corresponding to a reduction of 29%. By 2030, emissions are expected to drop to 38 million tonnes, corresponding to a reduction of 46%.[9]
- Non-ETS emissions are expected to be reduced by 20% in 2020 compared with 2005. Emissions are expected to meet the annual sub-targets in all years. Accumulated overachievement will amount to 15 million tonnes CO2-eq.
- Non-ETS emissions are expected to be reduced by 25% in 2030 compared with 2005. Emissions are not expected to meet the annual reduction targets in any year. The accumulated shortfall is expected to be 28 million tonnes CO2-eq. in 2030.[9]
- Emissions from LULUCF (land use and forestry) are expected to have fallen from 5 million tonnes CO2-eq. in 1990 to just over 3 million tonnes CO2-eq. in 2030. For the period 2021-2030 there is a preliminary basis for including an overall LULUCF contribution of 14.6 million tonnes CO2-eq. in Denmark's reduction efforts in non-ETS. The LULUCF statement is subject to considerable uncertainty.

7.2 The overall picture

Since 1990, which is the UN base year for calculating climate efforts, total annual greenhouse gas emission have fallen from 70.8 to 50.6 million tonnes CO2-eq. in 2017, corresponding to a reduction of 29%.[10] Up to 2030, emissions are expected to drop to 38 million tonnes, corresponding to a reduction of 46% compared with the UN base year.[9, 11]

Figure 32 illustrates that the most significant change will be within emissions related to the production of electricity and district heating, where observed emissions from 1990 to 2017 have dropped by almost 21 million tonnes CO2-eq, corresponding to a reduction of 63%. This trend is expected to continue up to 2030, when emissions will have been reduced to 3 million tonnes CO2-eq, corresponding to a reduction of 92% compared with 1990.

Emissions from other energy-related consumption, which includes individual heating of houses as well as heating and process energy consumption by industry and services, dropped by 34% from

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[9] In the absence of new measures and excluding emissions from land use and forestry (LULUCF).

[10] Statistical years have been adjusted for electricity trade and outdoor temperatures, which are described in background appendices to DECO19 (Danish Energy Agency, 2019a) .

[11] The global warming potentials (GWP) laid down in the Kyoto Protocol were used to calculate CO2-eq. for methane and nitrous oxide, for example (UNFCCC, 2014). Reporting to the UN under the Paris Agreement will begin in 2023, from when adjusted global warming potentials will be used (UNFCCC, 2019). For Denmark, this is expected to increase emission levels by between 0.03 and 0.3 million tonnes CO2-eq. annually from 1990 to 2017 and around 0.2 million tonnes CO2-eq. annually in the subsequent period. It has not yet been decided how to consider this change in the statement for the EU and in the reduction burden sharing.

1990 to 2017. Emissions will continue to drop up to 2030, when emissions are expected to have dropped by 48% compared with 1990.

Emissions from the transport sector increased by 16% from 1990 to 2017, but are expected to fall up to 2030, when emissions are expected to have increased by 11% compared with 1990. In 1990, the transport sector accounted for 17% of total emissions. The declining energy-related emissions mean that the transport sector is expected to account for 34% of total emissions in 2030. This will make the transport sector account for the largest share of total emissions.

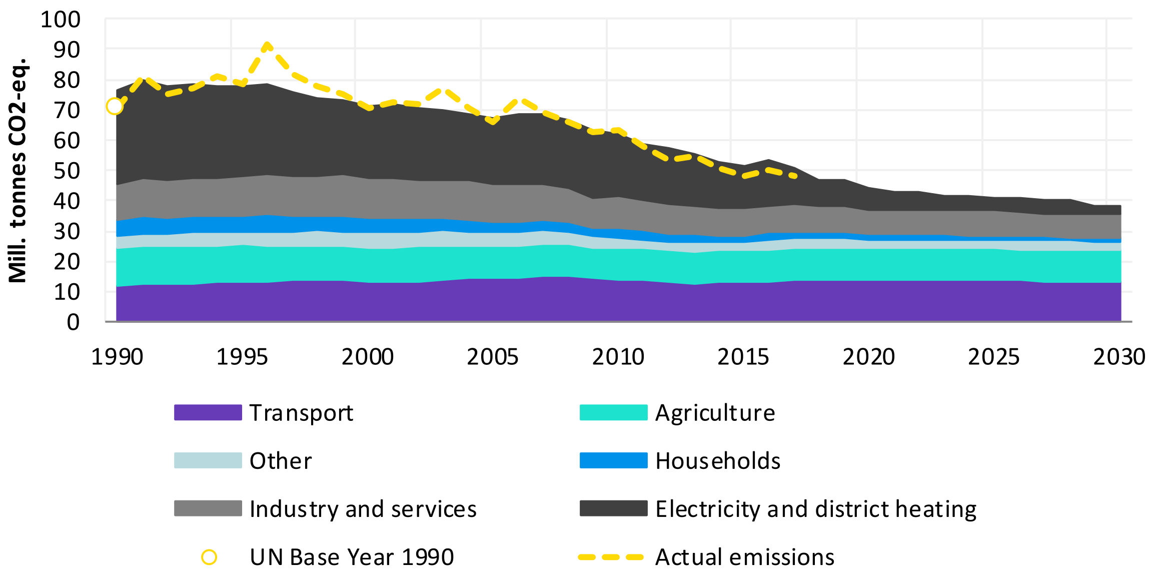
Emissions from agriculture have dropped by 16% from 1990 to 2017, and will drop slightly up to 2030, when emissions are expected to have dropped by 17% compared with 1990.

Other emissions, including process-related emissions from industrial gases, the chemicals industry, cement production and emissions from waste management and wastewater management, are expected to amount to 8% of total emissions in 2030. Emissions declined by 24% from 1990 to 2017, and will continue to decline slightly up to 2030, when emissions are expected to have dropped by 29% compared with 1990. Emissions from cement production are expected to increase due to economic growth, whereas emissions from other sources in this category are expected to decrease. Text box 2 presents a separate calculation of energy- and process-related CO2 emissions from industry and services.

In addition to energy and process-related emissions, emissions from land use and forests (LULUCF) are expected to be a source of net emissions of just over 3 million tonnes CO2-eq. in 2030. This is a drop from 5 million tonnes CO2-eq. in 1990. For the period 2021-2030, there is a preliminary basis for including an overall LULUCF contribution of 14.6 million tonnes CO2-eq. in Denmark's reduction efforts outside the ETS sector. The LULUCF statement is subject to considerable uncertainty.

The projections show that total greenhouse gas emissions will be reduced by 46% in 2030 relative to the 1990 UN base year in the absence of any new measures.[9]

Figure 32: Emissions of greenhouse gases by sector from 1990-2030 and in the 1990 UN base year [mill. tonnes CO2-eq.]. The statistical calculation of the area chart for 1990-2017 has been adjusted for electricity trade with other countries (electricity-trade adjusted (Appendix 2)). Reduction targets are based on observed (actual) emissions relative to the UN base year and excluding LULUCF. LULUCF emissions are calculated separately and are not included here.



7.3 Achievement of non-ETS reduction targets 2013-2020

Non-ETS emissions stem primarily from transport, agriculture, households, some industries and waste, and a number of small-scale CHP plants.

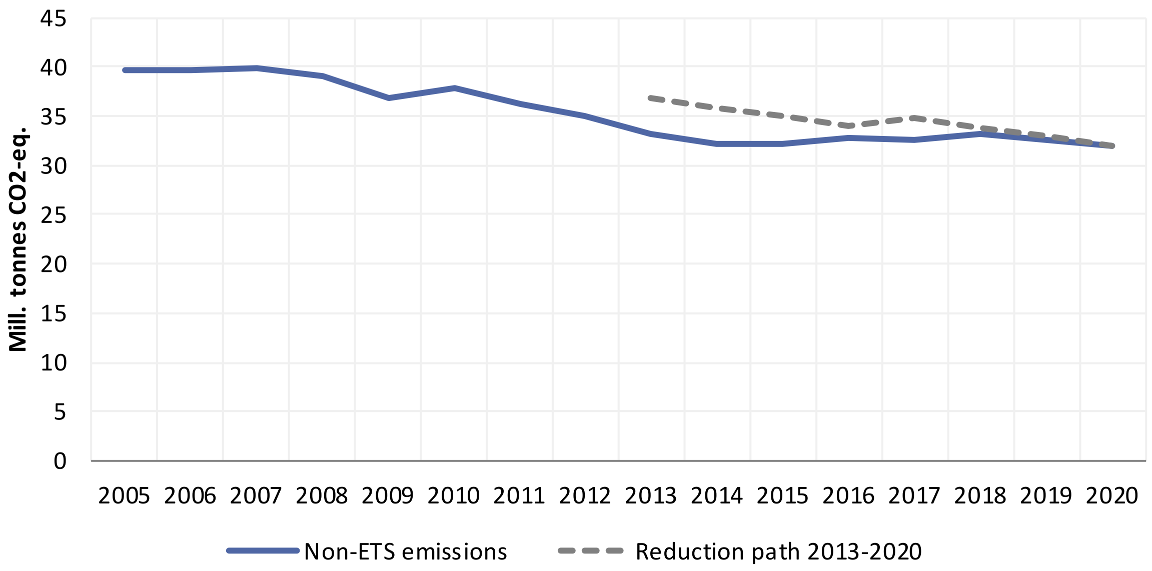
Under the 2009 EU Climate and Energy Package, Denmark is committed to reducing emissions from non-ETS sectors by 20% by 2020 relative to the 2005 level. This includes reaching gradually tighter annual sub targets. Overachievement in one year can be transferred to subsequent years up to 2020. In 2017, the permitted annual emissions for the years 2017-2020 were adjusted upwards.

Figure 33 shows that, in 2020, emissions are expected to be 32 million tonnes CO2-eq., corresponding to a reduction of exactly 20% compared to 2005. Denmark is expected to overachieve in all years in the commitment period. Total accumulated overachievement is expected to amount to 15 million tonnes CO2-eq. for the period.

The overachievement for the period cannot be carried forward to the next commitment period, 2021-2030.

The projections show that non-ETS emissions are expected to be reduced by 20% in 2020 compared with 2005. Emissions are expected to meet the annual sub-targets in all years. Accumulated overachievement will amount to 15 million tonnes CO2-eq. The overachievement cannot be carried forward to the next commitment period, 2021-2030.

Figure 33: Non-ETS emissions 2005-2020 and reduction commitment 2013-2020 [mill. tonnes CO2-eq.]



7.4 Achievement of non-ETS reduction targets 2021-2030 will fall short by 28 million tonnes CO2-eq.

Under the EU 2030 climate and energy framework, Denmark is committed to reducing emissions from non-ETS sectors by 39% by 2030 relative to the 2005 level, including meeting gradually tighter annual sub targets (European Commission, 2014, 2017b). Up to 2020, minor adjustments to the overall reduction targets may potentially occur.

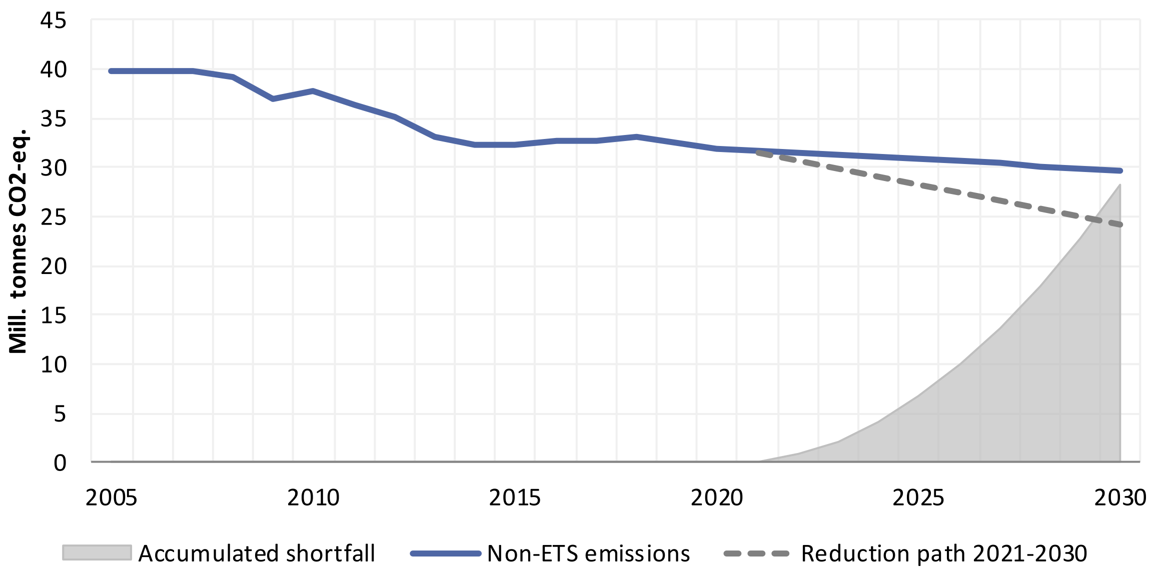
Figure 34 shows that, in 2030, emissions are expected to be 30 million tonnes CO2-eq., corresponding to a reduction of 25% compared to 2005, resulting in a shortfall of 14 percentage points relative to the commitment.

The figure also shows that, in all years throughout the period 2021-2030, emissions are *unlikely* to meet the annual sub targets. The accumulated shortfall is expected to be 28 million tonnes CO2-eq. in 2030.

The accumulated shortfall is sensitive to even small adjustments in annual emissions. Annual emissions are particularly sensitive to livestock numbers and to the composition of the vehicle fleet, including the number of electrified vehicles. The sensitivity analyses in Chapter 1 indicate that the shortfall could vary by plus/minus 6-8 million tonnes CO2-eq, corresponding to around 2% of total non-ETS emissions in the period.

The projections show that non-ETS emissions are expected to be reduced by 25% in 2030 relative to 2005. This means that the target of a 39% reduction by 2030 will be a further 14 percentage points short. Emissions are expected to exceed the annual sub-targets in all the years. The accumulated shortfall is expected to be 28 million tonnes CO2-eq. in 2030.

Figure 34: Non-ETS emissions 2005-2030, reduction commitment and accumulated shortfall 2021-2030 [mill. tonnes CO2-eq.].



7.5 Land use and forests (LULUCF) are a source of falling net emissions

Plants absorb CO2 from the atmosphere as part of their photosynthesis, and forests and farmland thus hold considerable stores of carbon. However, the stored CO2 may be released again into the air, for example in connection with burning trees or draining farmland. This cycle is referred to as LULUCF (Land Use, Land Use Change and Forestry) and is calculated separately.

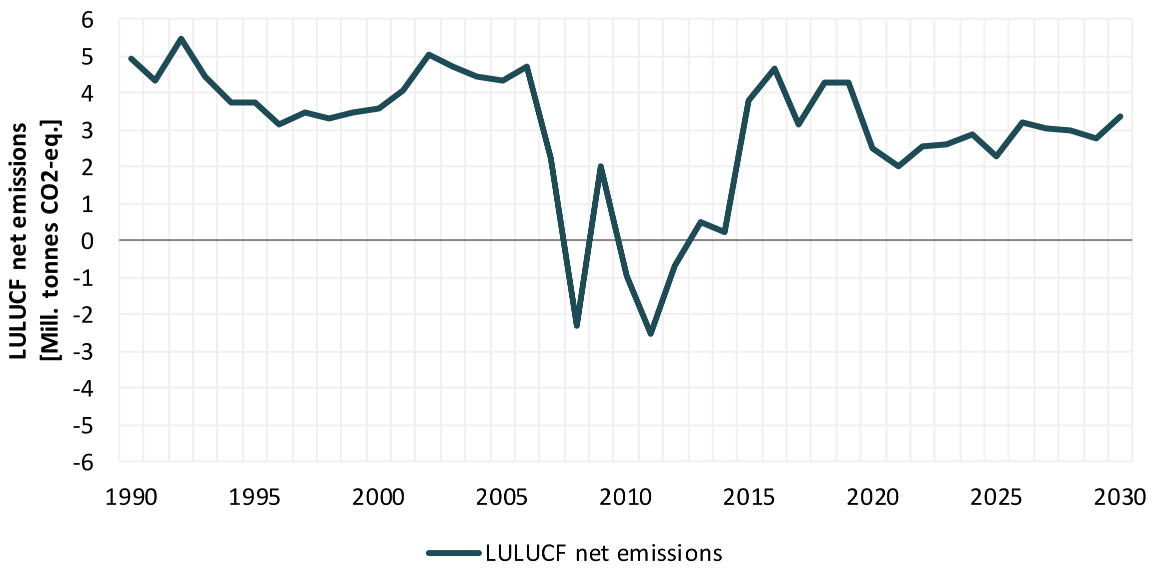
Figure 35 shows that LULUCF net emissions are expected to fall from 5 million tonnes CO2-eq. in 1990 to just over 3 million tonnes CO2-eq. in 2030. Furthermore, the figure shows considerable fluctuations in emissions from year to year, and, in some years, LULUCF is the source of net sinks of carbon. Calculations and projections of LULUCF are associated with considerable uncertainty.

Under the EU 2030 climate and energy policy framework, Denmark can include a LULUCF contribution in its reduction efforts outside the ETS sector (non-ETS) of up to 14.6 million tonnes CO2-eq. for the period 2021-2030 (European Commission, 2018b), provided that Denmark's carbon balance is improved by at least the same amount. The calculation of improvements in the carbon balance follows the LULUCF Regulation and is based on changes in LULUCF emissions relative to various reference levels (European Commission, 2018a).

The projections show, albeit with considerable uncertainty, that the improvement in Denmark's carbon balance in soils and forests preliminarily can be calculated at over DKK 14.6 million tonnes CO2-eq. The calculation is based on a calculation for agriculture and forestry up to 2017 and on a projection for agriculture (DCE, 2019). Furthermore, the calculation is based on a preliminary projection for forestry from the proposed Danish National Forests Accounting Plan 2021-2030, which is pending approval (Johannsen *et al.*, 2019).

The projections show, albeit with considerable uncertainty, that emissions from land use and forestry (LULUCF) are expected to have fallen from 5 million tonnes CO2-eq. in 1990 to just over 3 million tonnes CO2-eq. in 2030. The projections also show a preliminary basis for including an overall LULUCF contribution of 14.6 million tonnes CO2-eq. in Denmark's reduction efforts outside the ETS sector for the period 2021-2030. After completion of calculations, the statement of the area of organic lowlands was adjusted upwards. This may be of significance for the calculated LULUCF emissions/sinks. Thus, a specific assessment is required.

Figure 35: LULUCF emissions and sinks 1990-2030 [mill. tonnes CO2-eq.]



7.6 Emissions from manufacturing industry and services

Text box 2 presents a separate statement of CO2 emissions by manufacturing industry and services in 2030 broken down by use. Among other things, the statement shows that process-related CO2 emissions will make up an increasing share of total emissions in industry and services.

Text box 2: CO2 emissions in manufacturing industry and services in 2030.

In 2030, total CO2 emissions from manufacturing industry and services are expected to be around 7.2 million tonnes. Around 20% of these emissions will come from burning coal, coke, petroleum coke and fossil waste; around 30% will come from burning oil products; and around 25% will come from burning natural gas. Other emissions, corresponding to around 25% of the total emissions, comprise of process emissions such as emissions from limestone in connection with the production of cement.

Figure 36 shows total CO2 emissions by industry and services by energy service and fuel.

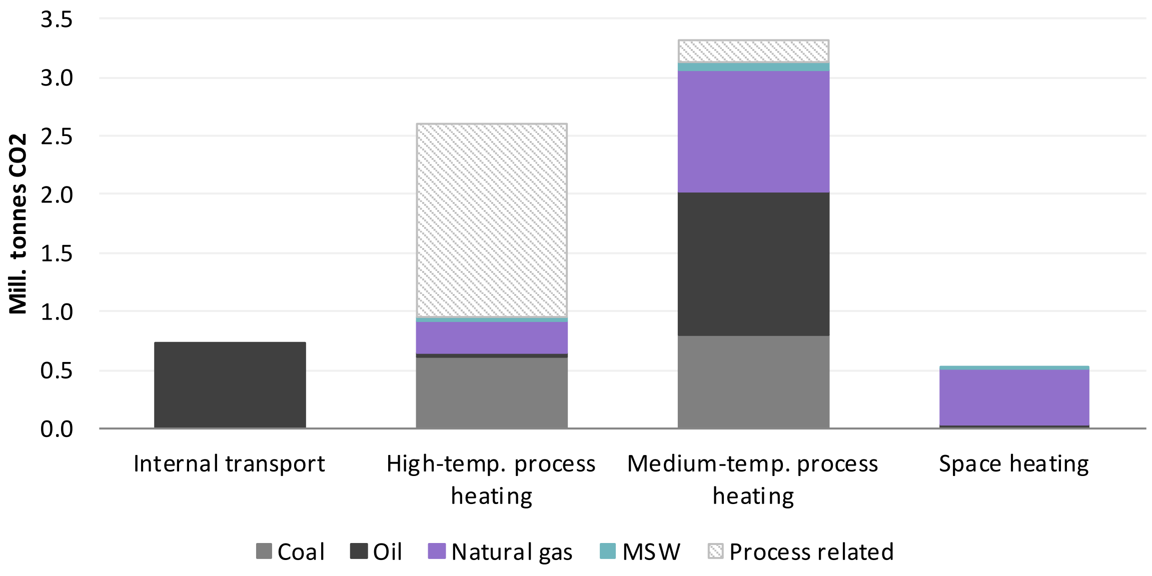
- Around 45% stem from energy-related consumption and from processes in connection with the production of medium-temperature heat such as drying/dehydration, heating and evaporation. Process-related emissions account for around 5% of this figure.

- Around 35% stem from energy-related consumption and from processes in connection with the production of high-temperature heat such as in the production of tiles and cement. Process-related emissions account for around 65% of this figure. Energy-related emissions stem primarily from burning coal, petroleum coke and coke.

- Around 10% come from energy-related consumption in combustion engines in internal transport, such as tractors and construction machines. All of these emissions stem from oil products.

- The remainder (around 7%) stem from energy-related consumption in the production of space heating. Burning natural gas in boilers accounts for around 90% of this figure.

Figure 36: CO2 emissions from industry and services in 2030 by energy service and type of fuel [mill. tonnes CO2].



7.7 Sensitivities and methodological considerations

Projections of greenhouse gas emissions are particularly sensitive to the efficiency of vehicles, the carbon price, technological developments, transport volume and changes in agricultural production.

Possible consequences of significant sensitivities for key results are further described in Chapter 8.

8 Sensitivity analyses

8.1 Main points

- Partial sensitivity analyses have been completed for selected central assumptions: electricity consumption by data centres, the carbon price, renewables deployment, sales of electrified vehicles, energy-efficiency improvements in industry and services, number of dairy cows, biofuels in aviation and coal-fired electricity production capacity.

- The partial sensitivity analyses show that uncertainty regarding central assumptions can have a significant impact on key results in the projections. For example, the analyses show that no onshore wind and solar PV deployment after 2024 could reduce the total share of renewables (RES) in 2030 from 54% to 50.5%.

8.2 Selection of sensitivities

Table 1 includes a number of sensitivities and parameter variations for use in partial sensitivity analyses. 'Partial' in this context means that a sensitivity analysis was performed for each parameter variation 'all else being equal', and the resulting effects can therefore not be readily aggregated.

The probability of variation in the individual sensitivities has not been assessed, nor has an overall risk analysis been performed.

Table 1: Selected sensitivities and parameter variations.

	Sensitivity	DECO19 baseline	Parameter variation 2030
A	Electricity consumption by data centres	'Linear growth'	The 'Denmark deselected' scenario, in which the electricity consumption of data centres is reduced by 80% in 2030 (COWI A/S for the Danish Energy Agency, 2018)
B	Carbon price	MoF baseline	Carbon price +/- 50%
C	Renewables deployment	DEA baseline	More renewables: + 450 MW offshore wind Less renewables: No onshore wind and solar PV deployment after 2024
D	Electrified vehicles	DEA baseline	More electrified vehicles: + 100% share of sales of new vehicles Fewer electrified vehicles: - 50% share of sales of new vehicles
E	Energy efficiency improvement in industry and services	DEA baseline	A smaller or greater effect of the energy saving pool for industry and services from 2021 to 2024
F	Dairy cattle	DEA baseline	+/- 15% in the number of dairy cows
G	Biofuels in aviation	DEA baseline	+ 10% biofuel blending in the aviation sector in 2030.
H	Coal-fired electricity production capacity	DEA baseline	More coal: A carbon price of DKK 50/tonne in combination with continued operation at Nordjyllandsværket (NEV3) as well as the possibility for coal-fired operation at Studstrupværket (SSV3) and Avedøreværket (AVV1) whenever viable. Less coal: End of operation at Fynsværket before 2030 when the heat capacity will be replaced by heat pumps and biomass boilers.

8.3 Result of partial sensitivity analyses

Figure 37 and Figure 38 compare the significance of the partial sensitivities for two key results, the renewables share (RES) and greenhouse gas emissions, respectively. Numerical values and other key results are in Appendix 6.

The two figures show the significance of the partial sensitivities for DECO19's central result for 2030.

Note the following about the partial sensitivities

A. Significantly lower electricity consumption by data centres in the 'Denmark deselected' scenario (COWI A/S for the Danish Energy Agency, 2018) can increase the renewable energy share by 1.6 percentage points. Emissions will not be affected, as electricity exports will increase proportionately to the lower electricity consumption.

B. A higher carbon price can increase the renewable energy share by 0.5 percentage points and the electricity price by 100 DKK/MWh.

C. No onshore wind and solar PV deployment after 2024 can reduce the renewables share by 3.5 percentage points and the electricity price by 10 DKK/MWh.

D. More electrified vehicles can reduce fossil gross energy consumption by 9 PJ and increase electricity consumption by 3.2 PJ (0.9TWh), which can reduce emissions by 0.6 million tonnes CO2-eq.

E. A greater effect of the energy saving pool for industry and services in the period 2021-2024 can reduce the fossil gross energy consumption by 1.5 PJ, which can reduce emissions by 0.1 million tonnes CO2-eq.

F. The number of dairy cows can affect emissions by +/- 0.5 million tonnes CO2-eq. if there is a change in the stock of +/- 15%.

G. Blending of 10% biofuels in the aviation sector can increase the renewables share by 0.6 percentage points and reduce fossil gross energy consumption by 4.6 PJ. The change in emissions has not been calculated here, as the emissions from international air travel are not included in the UN/EU statement.

H. More coal-fired electricity production capacity in combination with a lower carbon price can increase the fossil gross energy consumption by 22.6 PJ, which can increase emissions by 2.2 million tonnes CO2-eq. Less coal-fired electricity production capacity can reduce fossil gross energy consumption by 4.9 PJ and reduce emissions by 0.5 million tonnes CO2-eq.

The projections' partial sensitivity analyses show that central assumptions have a significant impact on key results in the projections. For example, the analyses show that no onshore wind and solar PV deployment after 2024 could reduce the total share of renewables (RES) in 2030 from 54% to 50.5% (3.5 percentage points). More coal-fired electricity production capacity in combination with a lower carbon price can increase emissions by 2.2 million tonnes CO2-eq.

Figure 37: Difference between baseline and partial sensitivities in the total share of renewables (RES). Red bars show reduced renewables shares; green bars show increased renewables shares.

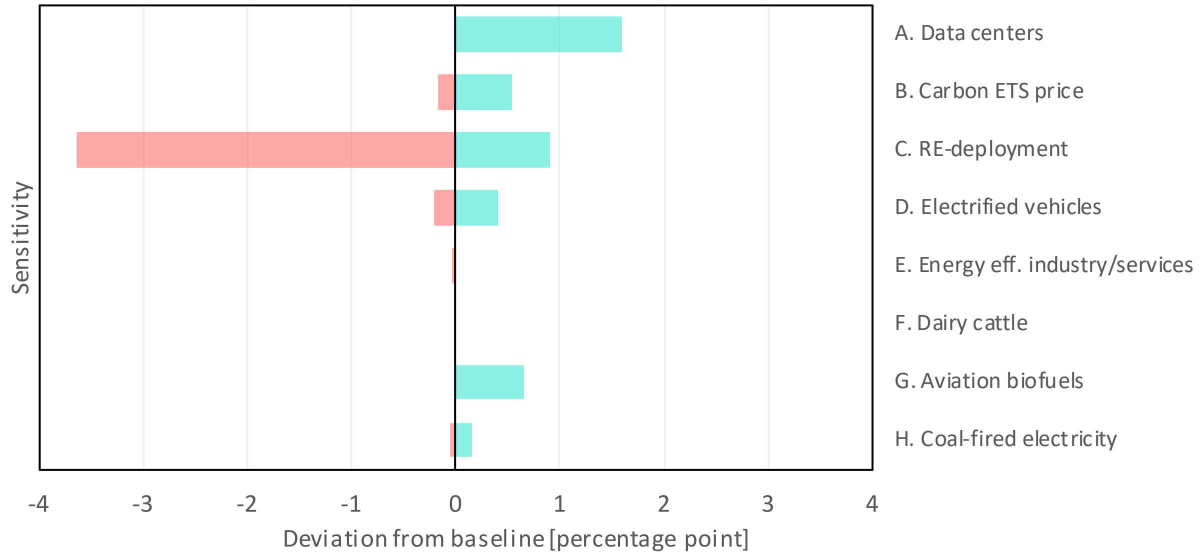
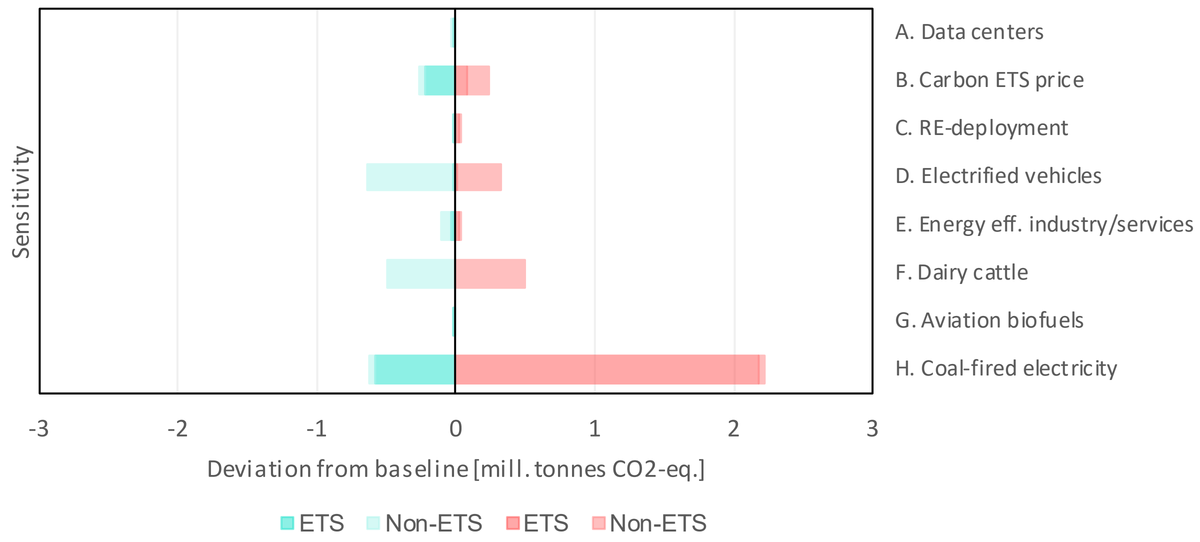


Figure 38: Difference between baseline and partial sensitivities in emissions broken down by ETS and non-ETS [mill. tonnes CO2-eq.]. Green bars show reduced emissions; red bars show increased emissions.



Appendix 1. Why does the report change from year to year?

For several reasons the report on Denmark's Energy and Climate Outlook changes from year to year:

- New regulation – for example the Energy Agreement of 29 June 2018, which includes financing for 3 offshore wind farms, relaxation of electricity taxes, removal of the cogeneration requirement in small-scale district heating areas as well as new energy saving efforts (Ministry of Energy, Utilities and Climate, 2018); new EU regulation in the transport area laying down emissions standards for passenger cars and vans (European Commission, 2019b); as well as the required implementation of new regulation of emissions standards for heavy-duty vehicles (European Parliament, 2019).
- Updated expectations for overall economic growth (Ministry of Economic Affairs and the Interior, 2019).
- Updated expectations for developments in fuel prices and the carbon price (Danish Energy Agency, 2019e; IEA, 2018).
- Updated expectations regarding specific projects and advances in energy technology in general, for example with regard to the number of full-load hours of wind power and solar PV in a normal year (Danish Energy Agency, 2019i).
- New market trends. For example updated expectations for the number of so-called PPA and guarantees of origin, which in turn are the basis for expectations in the projections for the deployment of commercial solar installations (ground-mounted solar farms) and onshore wind, in particular. [12]
- Updated expectations for the energy mix in electricity supply in the other 23 European countries included in the electricity market model of the analysis platform (ENTSO-E, 2018a, 2018b).
- Updates to statistics, which, for example, may result in altered expectations regarding the composition of household energy consumption for heating. For example, DECO19 is based on the most recent final energy statistics, Energy Statistics 2017 and Energy Production Statistics 2017 (Danish Energy Agency, 2019g, 2019c).
- Improvements to the model platform. For example, DECO19 uses a newly developed investment model for small-scale district heating areas. This model provides a stronger methodological approach to making projections about new investments as well as about decommissioning of existing facilities in the district heating sector.

[12] A Power Purchase Agreement (PPA) is a direct agreement between the investor/producer and consumer on trade in a specific production of electricity. For example, a PPA may help ensure a major consumer a guarantee of origin for purchases of renewable energy to cover its electricity consumption. A PPA may contribute to financing new capacity on market terms.

Appendix 2. Why are some statistical figures adjusted for electricity trade with other countries?

The results in DECO19 align with statistical principles and standards. Among other things, this means that the statistical statements (values for 2017 and earlier) of gross energy consumption and total greenhouse gas emissions are adjusted for annual net exchanges of electricity with other countries.

This adjustment is made to ensure that the statistical statements of gross energy consumption and greenhouse gas emissions reflect the actual interrelated system impacts of developments in Denmark's energy consumption. Without this adjustment for trade in electricity, Denmark could reduce its gross energy consumption and CO2 emissions by simply importing electricity produced from coal south of the border.

In periods with net imports, the adjustment for trade in electricity approximately reflects Denmark's gross energy consumption and CO2 emissions if Denmark had produced its own electricity corresponding to its net imports of electricity in the current electricity supply system.

In periods with net exports of electricity, the adjustment for trade in electricity approximately reflects reduced gross energy consumption and CO2 emissions in the countries receiving the exported electricity.

With this adjustment, the calculations provide a representative energy and emissions impact of annual net exchanges of electricity with other countries. This impact figure is then included in the relevant result for the year. The method is based on the assumption that marginal electricity production in an interlinked European energy system can be represented by the average composition of thermal electricity production plants in Denmark year by year. In this context, thermal electricity production plants cover electricity production from coal, natural gas, oil and solid biomass (wood pellets and wood chips). In the Energy Statistics report, adjustment for trade in electricity is performed on the basis of a historical 5-year average.

The Danish Energy Agency's method for statistical computation of the adjustment of a net-exchange of electricity with other countries is assessed and updated periodically, most recently in 2016 (Danish Energy Agency, 2016).

The statements of gross energy consumption and CO2 emissions for statistical years have moreover been adjusted for fluctuations in temperature (climate-adjusted) relative to a statistically determined normal year.

Normal years have been used for projection years (2018 and onward), and projected results in DECO19 have not been adjusted for foreign trade in electricity. The reason that the projected results in DECO19 have not been adjusted for foreign trade in electricity is that Denmark is expected to become a systematic exporter of electricity over the projection period, and that Denmark's domestic electricity supply is expected to be converted to non-thermal production technologies, which means that any future method of adjusting for trade in electricity will probably have to be updated to reflect this. Projected results for total gross energy consumption and total greenhouse gas emissions for the period 2018-2030 have therefore been stated as observed (actual) consumption and emissions in normal years.

Appendix 3. Policy measures with implications for DECO19

The following describes elements of policy measures with particular implications for DECO19, see Figure 1 in Chapter 1.3.

In principle, the Energy Agreement of 29 June 2018 (Ministry of Energy, Utilities and Climate, 2018) covers the period up to and including 2024. However, since the last of the three offshore wind farms under the agreement is not expected to be commissioned until 2030, the agreement can be interpreted to affect the entire projection period. In addition to three new offshore wind farms, the Energy Agreement ensures funding for new biogas production; continued relaxation of electricity taxes; new technology-neutral tendering procedures for solar PV, onshore wind and nearshore offshore wind; as well as new energy saving efforts in place of the energy saving scheme (energy saving efforts of energy companies), which runs until the end of 2020 (Danish Energy Agency, 2019d). The new energy saving scheme includes subsidy pools for energy saving efforts by industry and services as well as by households. Furthermore, the scheme includes a campaign to raise awareness about how households can save energy. DECO19 moreover includes the effect of abolishing Annex 1 of the Danish Electricity Tax Act as part of the Energy Agreement, which will allow more business and industry sectors to seek refunds for electricity taxes. Finally, removal of the cogeneration requirement and the fuel obligation in small-scale district heating areas under the Energy Agreement, as well as the Danish Energy Agency's possibility to grant exemption from the cogeneration requirement in large-scale district heating areas, are also included. Removal of the cogeneration requirement, including removal of the possibility to be exempted from this requirement, has implications for the expected scope of the conversion of facilities from coal-based and natural-gas-based CHP generation to production based on other energy supply technologies such as heat pumps and biomass boilers.

The Energy Agreement earmarks a financial reserve for even more renewable energy from 2025 - the so-called RE reserve. The effect of this element has not been included in DECO19 because any realisation of the RE reserve must be based on a period assessment of developments *without* realisation of the RE reserve. Furthermore, the Energy Agreement's pool for the deployment of green transport has yet to be realised as concrete measures and has therefore also not been included.

The Energy Agreement's relaxation of electricity taxes prolongs and expands current relaxations agreed in connection with the Agreement on Business and Entrepreneurial Initiatives of 12 November 2017 (Ministry of Industry, Business and Financial Affairs, 2017). In the energy area, this agreement is valid up to and including 2020.

The PSO tariff, which is paid for over the electricity bill, is being phased out and will be discontinued from year end 2021 (Danish Energy Agency, 2018b).

An agreement on a temporary relaxation of the registration tax on electrified vehicles (Danish Ministry of Taxation, 2018) has been included as having an effect on sales of vehicles up to 2022.

Earlier subsidy schemes for new offshore wind, new biomass-based CHP and new biogas production will lapse during 2019 and will be replaced by the technology-neutral tendering scheme. Existing facilities established under earlier subsidy schemes will continue under existing terms and conditions. However, the 2018 amendment to the Promotion of Renewable Energy Act and to the

Electricity Supply Act stipulates a revised price supplement for biomass-based electricity generation based on facility-specific depreciation in accordance with EU state aid rules.

Furthermore, production-independent support for small-scale CHP production (the so-called basic amount) and support for establishment of large electricity-driven heat pumps ended at year end 2018 (Danish Energy Agency, 2018a).

The technology-neutral tendering procedure conducted in the period 2018-2019 has been included with the effects achieved from this initiative. Upcoming technology-neutral tendering procedures have been included as an element in the Energy Agreement and have been distributed across technologies as appropriate.

Agreements funded by the Danish Finance Act 2019 (Ministry of Finance, 2018) have been included as having an effect on some of the emissions from agriculture; on emissions of certain greenhouse gases from cooling systems; as well as on reduced leakages from biogas plants from 2021.

EU product standards such as the Ecodesign Directive and the Energy Labelling Directive, and standards for transport vehicles, have been included as having an effect throughout the projection period with the restrictions and expansions already decided by the EU.

In principle, the EU Waste Framework Directive will have effect throughout the entire projection period. However, there is currently no basis for any new expectations with regard to the composition of waste or the calorific value, including the renewable energy share of waste for incineration, just as the existing incineration capacity is assumed to stay the same.

The Danish building regulations will continue, in which transitioning to building class 2020 will be optional, and the regulations will be current throughout the projection period.

Other existing taxes and subsidies will continue to apply throughout the projection period.

Appendix 4. DECO19's model platform

The following describes elements in DECO19's model platform, see Figure 2 on page 15.

Figure 2 shows the overall elements in the model platform, with inputs on the left and outputs on the right.

Inputs include: projection of emissions based on, amongst other things, DECO19's energy balance and on emissions from agriculture, for example, in collaboration with the Danish Centre for Environment and Energy (DCE) at Aarhus University; projections by the Danish Ministry of Finance and the Ministry of Economic Affairs and the Interior of economic and demographic developments, business productivity and CO2 emission allowances; the International Energy Agency's (IEA's) projection of world market prices of fossil fuels adapted to a Danish level; detailed plant data on Denmark's energy plants, based, among other things, on the Danish Energy Agency's energy production statistics and master data register; Statistics Denmark's input-output matrices for exchanges between sectors; the Danish Energy Agency's technology catalogues; and the projection of the electricity demand, energy production capacity and interconnectors of 23 European countries, based on data from the European Network of Transmission System Operators, ENTSO-E.

Output includes (year-by-year and hour-by-hour up to 2030) energy consumption by sector, by use and by technology; energy balances for supply facilities and for district heating areas; greenhouse gas emissions; key indicators such as shares of renewables in accordance with the requirements of the Renewable Energy Directive (Eurostat, 2018); electricity exchange and the electricity price for each of the 15 European electricity market areas included in the electricity market model; security of electricity supply; fiscal revenues; socioeconomic and corporate financial performance; as well as developments in the energy intensities of businesses.

The model platform integrates the following sub models:

- The summary model "Denmark's Energy and Climate Model", which integrates the sector models mentioned below and results from the DCE's emissions model such as to provide an overall projection result at system level. Furthermore, the summary model forms the basis for the comparative analyses of projection scenarios vis-a-vis impact assessments at system level.

- RAMSES, which models electricity and district heating supply. RAMSES is a technical-economic model for operations optimisation, which is based on a detailed description of all energy-producing facilities and district heating areas in Denmark's energy system as well as on an aggregated description of the electricity production plants in the European electricity markets included in the model, including interconnectors between these markets. RAMSES simulates operations in the interlinked European energy system on an hourly basis. RAMSES does not automatically take account of new investments. RAMSES includes Denmark as well as 23 countries broken down by 15 European electricity market areas. Trends in new production capacity are defined partly exogenously based on specific knowledge as well as on capacity development models for, among other things, wind power and solar PV, and partly based on a coupling to DH-Invest, which is a new investment model for small-scale district heating areas.

- IntERACT, which models energy consumption by industry and services and households. The model comprises two sub models: An economic model which describes the macroeconomic correlations using a neoclassical, general equilibrium model and a technical energy system model based on the IEA' s TIMES model (IEA-ETSAP, 2018). The model describes fundamental energy-technology, thermodynamic and physical relationships on a theoretical energy-economics basis. The model uses output data from RAMSES on electricity prices and district heating prices.

- DH-INVEST, which is an investment model for small-scale district heating areas. The model simulates operations and investments for each district heating area in order to determine investment scenarios that are optimal from the perspective of corporate finances. The investment scenarios include decommissioning of existing facility units. The investment model is integrated with RAMSES and uses a common assumptions basis, after which the calculated changes in capacity for the individual district heating area are used by RAMSES in its modelling of Denmark's electricity and district heating system.

- SISYFOS, which simulates the capacity adequacy (security of supply) of the electricity system. SISYFOS is a Monte Carlo simulation model which, based on rolls of dice, simulates different situations with outages of power plants and/or power lines in the electricity system. Using time series for electricity demand, wind power, solar PV, etc., the model identifies combinations of events which can lead to capacity shortages. Loss-of-probability (LOLP) is calculated and converted into number of minutes' capacity shortage per year. Furthermore, expected unserved energy (EUE) is calculated using a methodology developed by Energinet, along with the associated average number of outage minutes.

- FREM, which models energy consumption in the transport sector. Amongst other things, FREM is based on input from the Danish Transport, Construction and Housing Authority, which uses the National Transport Model (LTM) (Technical University of Denmark, 2018) to describe developments in road traffic and energy consumption by railways. FREM projects road transport based on projections for growth in traffic volume, developments in the energy efficiency of vehicles by 44 vehicle categories and survival rates, journeys as a function of the age of vehicles, as well as choice of vehicle. FREM projects energy consumption in air transport based on developments in GDP and population numbers, as well as expected developments in energy efficiency in aviation.

- The PSO model, which is used to calculate expected future expenditure on subsidies for electricity production. The model calculates expenses for offshore wind, onshore wind, biogas, solar PV, CHP production and more. The results are used to determine the PSO tariff and in connection with fiscal budgeting. The model uses output data from RAMSES on electricity prices, electricity consumption and electricity production. The model also models relevant technology subsidy schemes.

- Technology Deployment Models for offshore wind, onshore wind, solar PV and biogas use, which model the profitability of technology investments in terms of corporate finances against the profitability requirements of relevant investors, which means the models model the most probable capacity deployment scenario against the current investment and operating conditions.

Appendix 5. Why are there discrepancies between DECO19 figures and energy statistics?

DECO19 was prepared and produced at a time when 2017 was the most recent final statistical year, and so all references to climate and energy figures for 2017 and earlier are based on statistical statements. Results for 2018 and onward, on the other hand, are based on calculation of normal years for wind production, precipitation (of significance for foreign, hydro-based electricity production), degree days (of significance for heating demand) and standard production conditions in foreign electricity supplies, for example.

At the time of writing, it was clear, for example, that wind production in 2018 was 10-15% lower than in a normal year, just as it was well known that a particularly warm summer led to extraordinary electricity production conditions in Europe, which meant that several German coal plants and French nuclear power plants had to limit their production for longer periods due to cooling demand. This influenced the electricity market and the composition of electricity production in Denmark in 2018, which could mean that fuels breakdown and emissions will deviate from an expected normal year.

Since, at the time of writing, there is no final and overall statistical basis available for 2018, the projected results for 2018 have been based on a normal year. Because of this methodological approach, the projected results for 2018 are expected to deviate from the upcoming final energy statistics for 2018.

DECO19's model platform will accurately model statistical years where all assumptions turn out to be correct and any deviations from the normal year are known.

Note in general that statistical years may be characterised by large fluctuations. DECO19 describes trends over a longer period of years, while the statistics report observed (actual) conditions in historical years. DECO19 focuses on average trends up to 2030, and model results for normal years in the intervening period, including greenhouse gas emissions, are likely to deviate from subsequent statistical statements.

DECO19 projects and describes trends over a number of years. As a consequence of this, result values for 2018 and 2019 have been omitted in the results tables in the accompanying spreadsheets. However, the figures in this report include all model-calculated figures to best illustrate trends.

Due to the model platform's indirect management of the energy statistics, there could also be marginal differences between DECO19 and the energy statistics with regard to the statement of statistical values. For an accurate energy statistics statement, see the Danish Energy Agency's energy statistics (Danish Energy Agency, 2019g).

Appendix 6. Result of sensitivity analyses

Table 2 shows result values for partial sensitivity analyses with reference to the list in Table 1 on page 67.

Table 2: Sensitivity results for 2030 calculated as delta values (differences) relative to the baseline. Values are stated for 2030."~" indicates an approximate value. "NA" (Not Applicable) indicates that no calculation was performed.

				Electricity			Carbon emissions	
	Description	Renewables share (RES) [Percentage points]	Fossil gross energy consumption [PJ]	Consumption [TWh]	Price [DKK/MWh]	Imports [TWh]	Non-ETS [Mill. tonnes CO2-eq.]	Total [Mill. tonnes CO2-eq.]
-	DECO19 Baseline	54	378	45	344	-6.2	30	38
A	Data centres 'Denmark deselected'	+1.6	-0.4	-5.7	-8.2	-5.6	~0	~0
B+	Higher carbon price	+0.5	+0.4	-0.1	+99.8	-1.1	+0.1	-0.1
B-	Lower carbon price	-0.2	+0.5	~0	-27.9	+0.2	~0	~0
C+	Increased offshore wind deployment	+0.9	-0.1	-	-3.4	-1.7	~0	~0
C-	No new solar PV and onshore wind after 2024	-3.6	+0.3	-	+9.6	+7.1	~0	~0
D+	Increased sales of electrified vehicles	+0.4	-8.7	+0.9	+1.3	+0.9	-0.6	-0.6
D-	Reduced sales of electrified vehicles	-0.2	+4.4	-0.5	-0.7	-0.5	+0.3	+0.3
E+	More efficiency improvement, industry/services	~0	-1.5	-0.1	~0	~0	-0.1	-0.1
E-	Less efficiency improvement, industry/services	~0	+0.6	+0.1	+0.1	~0	~0	~0
F+	More dairy cows	-	-	-	-	-	+0.5	+0.5
F-	Fewer dairy cows	-	-	-	-	-	-0.5	-0.5
G+	Increased share of biofuels in aviation	+0.6	-4.6	-	-	-	*NA*	*NA*
H+	More coal-fired electricity production capacity	~0	+22.6	+0.1	-44.3	-2.7	~0	+2.2
H-	Less coal-fired electricity production capacity	+0.2	-4.9	+0.2	+1.1	+0.9	~0	-0.5

Appendix 7. Background appendices

Background appendices (in Danish) have been published along with DECO19 documenting assumptions and detailed results, and including spreadsheets with key figures presented in the report.

The background appendices can be downloaded from http://ens.dk/outlook.

0. Spreadsheet with selected assumptions
1. Fuel prices and carbon prices
2. Greenhouse gasses and agriculture
3. Overarching assumptions
4. Taxes and subsidies
5. Transport
6. Electricity and district heating, as well as interconnectors
7. Offshore wind
8. Onshore wind
9. Solar PV
10. Waste incineration
11. Biogas
12. Oil and gas
13. Electricity price

Appendix 8. References

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