Danish Energy Agency

Denmark's Energy and Climate Outlook 2018

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

Denmark’s Energy and Climate Outlook 2018: Baseline Scenario Projection Towards 2030 With Existing Measures (Frozen Policy)
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Glossary

Gross energy consumption (adjusted): Gross energy consumption describes the total input of primary energy to the energy system. Gross energy consumption is found by adjusting observed energy consumption for fuel consumption linked to foreign trade in electricity, as well as for changes in outdoor temperature relative to a normal year.

Final energy consumption: The final energy consumption expresses energy consumption delivered to end users, i.e. private and public enterprises as well as households. The purpose of this energy use is the manufacture 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, cleaning and bitumen for paving roads. 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, services, and households is calculated exclusive of consumption for transport purposes. Moreover, final energy consumption excludes cross-border trade in oil products, defined as the quantity of petrol, gas/diesel fuel and pet-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, 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. Unlike final energy consumption, gross final energy consumption excludes consumption for non-energy purposes and includes 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. To this figure is added own consumption of energy in connection with production of electricity and district heating.

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, biofuels, renewable natural gas (RNG), biodegradable waste, and biogas). Renewable natural gas (RNG) is biogas that has been upgraded to meet the supply requirements for gas in the grid.

Renewables shares: Total renewables shares (RES), for electricity consumption (RES-E) and for transport (RES-T) are calculated according to the Eurostat EU calculation method. For a detailed description of this see Eurostat SHARES (Eurostat, 2018).

- RES: Total renewables share according to the EU calculation method. Calculated as observed (actual) renewable energy consumption divided by gross final energy consumption.

- RES-E: The renewables share for electricity supply according to the EU calculation method. Calculated as observed renewable energy consumption in electricity production divided by domestic electricity consumption plus grid losses and own consumption.
- RES-T: The renewables share in transport according to the EU calculation method. Calculated as observed (actual) renewable energy consumption for electricity used for transport purposes (based on RES-E) plus consumption of biofuels divided by total fuel consumption for transport purposes using a number of multipliers. All modes of transport are included, also air transport. A distinction is made between uses and between first and second generation biofuels. The multipliers include: 2x renewable energy from sustainable biofuels for all transport modes + 5x RES-E renewables share of electric road transport + 2.5x RES-E renewables share of electric railway transport and 'Other renewables' (including hydrogen) divided by the total electricity and fuel consumption for transport using similar multipliers (except for the 5x-multiplier, 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:

- CO2 (carbon dioxide): Primarily from burning of fossil fuels such as coal, oil and natural gas.
- CH4 (methane): Primarily from organic processes such as the digestion system of animals or waste composting.
- N2O (nitrous oxide): Primarily from nitrogen conversion.
- F gases: Primarily from 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, industries and 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 baseline 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 combined European effort is shared between Member States according to a national distribution agreed 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 economic or physical output.

Abbreviations

Waste (bio)	The biodegradable share of combustible waste.
Waste (fossil)	The non-biodegradable share of combustible waste.
DECO17	Denmark's Energy and Climate Outlook 2017 (last year's baseline projection)
DECO18	Denmark's Energy and Climate Outlook 2018 (the current baseline projection)
GDP	Gross domestic product
CO2-eq.	CO2 equivalents
DEA	Danish Energy Agency
DCE	Danish Centre for Environment and Energy, Aarhus University
DK1	Electricity price area 'Western Denmark'
DK2	Electricity price area 'Eastern Denmark'
DREAM	Danish Rational Economic Agents Model
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 modelled 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
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IPCC	The UN's Intergovernmental Panel on Climate Change
LTM	National Transport Model (LTM), Technical University of Denmark
LULUCF	LandUse, LandUseChange and Forestry
MAF	Mid-term Adequacy Forecast - ENTSO-E
PSO	Public Service Obligations
RES	Renewable Energy Share - Renewables share
RES-E	Renewable Energy Share Electricity - Renewables share in electricity consumption
RES-T	Renewable Energy Share Transportation – Renewables share in transport
TYNDP	10-year Network Development Plan - ENTSO-E
RE	Renewable energy
HP	Heat pump

1 Welcome to Denmark’s Energy and Climate Outlook 2018: Frozen Policy

Denmark’s Energy and Climate Outlook 2018 (DECO18) is a technical assessment of how Danish energy consumption and energy production, as well as Danish greenhouse gas emissions, will evolve over the period to 2030 based on the assumption of a frozen policy scenario (with existing measures).

The purpose of the DECO18 is to describe where Denmark stands and what challenges Denmark faces with regard to meeting its energy and climate policy targets.

The DECO18 is therefore an important planning tool in setting Danish energy and climate policy, as well as an important reference for assessing the impacts of new policy initiatives.

This document is an English translation of the original document in Danish published in April 2018. The details of the baseline projection included here are based on the assumption of a frozen policy scenario and include existing measures as of March 2018. On June 29th 2018, the Danish Government and all parties in Parliament agreed to a new set of measures to be introduced from 2020 to 2024. These measures, and any measures decided upon after March 2018, are not included in the current baseline projection, and will be included in the next Denmark’s Energy and Climate Outlook, which will be published in 2019.

1.1 What is meant by frozen policy?

The DECO18 describes a frozen-policy scenario for energy and climate developments in Denmark up to 2030.

A frozen-policy scenario describes a scenario in which no new policies are introduced.

This assumed 'policy freeze' pertains to the climate and energy area only.[1] This means that economic growth, demography, the road system, the housing stock, international fossil fuel prices, and the price of such products as electric cars and photovoltaic solar modules, for example, are assumed to evolve independently of the 'policy freeze'.

Furthermore, the assumed 'policy freeze' applies for Denmark only. The DECO18's model platform is underpinned by assumptions about trends in electricity supply in 23 other European countries. The assumed developments outside Denmark are based on the individual countries' reported trends and do not necessarily reflect a frozen-policy approach.

Nor does the frozen-policy approach mean developments will come to a halt. Regulation that has already been decided, in combination with remaining assumptions and trends, form the basis for a technical assessment of the most probable future trends in energy demand and in deployment of onshore wind, photovoltaic solar modules, heat pumps and electric cars, etc. The basis for this assessment is a well-defined methodology basis which, for example, is underpinned by the individual technologies' expected technical-economic development and the individual stakeholders’ options and financial viability requirements (Danish Energy Agency, 2018b). Large, existing

[1] And so-called non-energy.

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.

1.2 How can the DECO18 be used?

The DECO18 can be used to estimate the extent to which Denmark's energy and climate targets will be met assuming current regulation and decision processes.

For example, the DECO18 relates analytically to the binding targets prescribed in the 2009 EU Climate and Energy Package, which includes the Renewable Energy Directive and the Climate Directive (EU, 2009a, 2009b). These EU directives set out binding renewable targets for Denmark in the form of a total renewables share of 30% by 2020; a renewables share of 10% in transport by 2020; and a 20% carbon reduction in non-ETS greenhouse gas emissions in 2020 relative to 2005.

Similarly, the DECO18 provides a basis for estimating Denmark's contribution to achieving the EU targets for 2030 in the absence of any new initiatives. In October 2014, the EU heads of state and government agreed that, by 2030, the EU as a whole must reduce its greenhouse gas emissions by at least 40% relative to the 1990 level, that the renewables share must be at least 27%, and that EU energy efficiency must improve by at least 27% (European Commission, 2014). There are national sub targets for non-ETS greenhouse gas emissions up to 2030. These targets have been taken into account in the DECO18. The remaining targets are total EU targets, and the individual Member States are obliged to report their contributions to these targets in the years to come (European Commission, 2017b).

Furthermore, the DECO18 also provides the basis for assessing a number of national and local targets, for example the goal set out in the Government's Political Platform that Denmark is to cover at least 50% of its energy demand from renewables in 2030 (Danish Government, 2016), the goals of Denmark's two largest cities, Copenhagen and Aarhus, to become carbon neutral by 2025 and 2030, respectively (City of Copenhagen, 2012; City of Aarhus, 2016), and the goal of Denmark's fourth largest city, Aalborg, to convert the city's coal-fired CHP plant to green energy (Aalborg Forsyning, 2017). These goals may be both achievable and realistic, but will not be reflected in the projections of the DECO18 until the targets have been realised in the form of specific initiatives for which there is a high probability of target achievement.

1.3 Why does the report change from year to year?

The report on Denmark's Energy and Climate Outlook changes from year to year. There are a number of reasons for this.

- New policy/regulation, for example the November 2017 Government Agreement on Business and Entrepreneurial Initiatives, which reduces the tax on electric heating (Ministry of Industry, Business and Financial Affairs, 2017), the May 2017 amendment to the subsidy scheme for photovoltaic solar modules that introduced so-called instant settlement[2] (Danish Government, 2017a), as well as the discontinuation of the subsidy scheme for onshore wind in February

[2] With instant settlement, a tax is paid on electricity supplied from the collective electricity supply grid, while only the electricity consumed directly from the self-production of solar modules is exempt from paying electricity tax.

2018 which will be replaced in 2018/19 by a technology-neutral tendering scheme (Danish Government, 2017b).

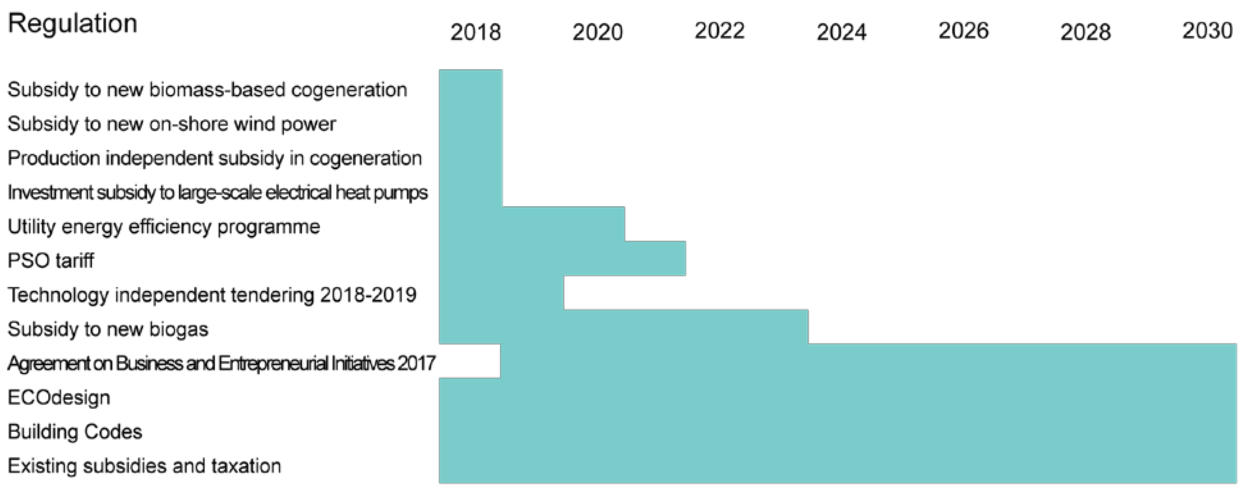
- Updated expectations for overall economic growth (Danish Ministry of Finance, 2017).
- Updated expectations for developments in fuel prices (Danish Ministry of Finance, 2017; IEA, 2017).
- Updated expectations for advances in energy technology (Danish Energy Agency, 2018k).
- Update of statistics, which, for example, may result in altered expectations regarding the composition of household energy consumption for heating.
- Improvements to the model platform.

1.4 The scope of current regulation

Figure 1 illustrates the time scope of Danish regulation in the climate and energy area of special significance for the DECO18. As can be seen from the figure:

- The subsidy scheme for new onshore wind, new biomass-based CHP and new biogas will be discontinued from 2018, 2019 and 2023, respectively. Existing plants will continue to receive subsidies according to the rules in force before the scheme was discontinued.
- Production-independent support for small-scale CHP production ends in 2019 (Danish Energy Agency, 2018g).
- Support to establish large, electricity-driven heat pumps ends in 2019 (Danish Energy Agency, 2018j).
- A technology-independent tendering procedure will be carried out in 2018-2019 (Danish Government, 2017b).
- The Agreement on Business and Entrepreneurial Initiatives (Ministry of Industry, Business and Financial Affairs, 2017) is included with the agreed impacts. Mentioned, but not yet finally agreed elements, for example a further reduction of the tax on electric heating from 2021, are not included.
- The PSO tariff will be phased out from 2017 and will be discontinued the end of 2021 (Danish Energy Agency, 2018i).
- The scheme concerning energy saving efforts by energy companies will be discontinued at the end of 2020 (Danish Energy Agency, 2018e).
- EU production standards in the form of the ECOdesign Directive and the Energy Labelling Directive will continue.
- The Danish building codes will continue, and transitioning to building code 2020 will be optional.
- Other existing taxes and subsidies will continue.

Figure 1: The time scope for Danish regulation of special significance for the frozen-policy scenario in the DECO18.



1.5 Model platform - the Danish Energy Model

Since 1984, the Danish Energy Agency has developed a comprehensive integrated model platform for making projections and impact analyses in the energy and climate area.

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

Inputs include the Danish Ministry of Finance's projection of economic and demographic developments, industrial productivity and CO2 allowances (Danish Ministry of Finance, 2017); the International Energy Agency's (IEA's) projection of world market prices of fossil fuels (IEA, 2017), adapted to Danish level; detailed plant data on Danish energy plants, based, for example, on the Danish Energy Agency's energy production statistics (Danish Energy Agency, 2018d); Statistics Denmark's input-output matrixes for exchanges between sectors (Statistics Denmark, 2018a); the Danish Energy Agency's technology catalogues (Danish Energy Agency, 2018k); 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 (Danish Energy Agency, 2018h; ENTSO-E, 2017, 2018).

Output includes (year-by-year and hour-by-hour up to 2030) detailed energy balances for plants, sectors and district heating areas, key indicators such as the shares of renewables in accordance with the statistical norms of Eurostat (Eurostat, 2018), emissions calculations in collaboration with the Danish Centre for Environment and Energy (DCE) at Aarhus University, electricity exchange and the electricity prices in eastern and western Denmark and for each of the other 23 European countries, broken down by 13 electricity market areas included in the model, fiscal revenues impacts, socioeconomic and corporate financial performance, as well as developments in the energy intensities of industry and services.

The model platform integrates the following sub models:

- RAMSES 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 the Danish 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 this interlinked European energy system on an hourly basis. RAMSES does not automatically take account of new investments. Developments in new capacity are determined exogenously based on the technology deployment models (described below). For the DECO18, RAMSES has been updated with new countries and therefore now includes Denmark as well as 23 European countries broken down by 15 market areas described based on ENTSO-E data on current plans for capacity deployment and interconnectors. Furthermore, for the DECO18, RAMSES has been updated with country-specific renewable energy subsidy rates and production profiles.

- IntERACT models energy consumption in industry, 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 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.

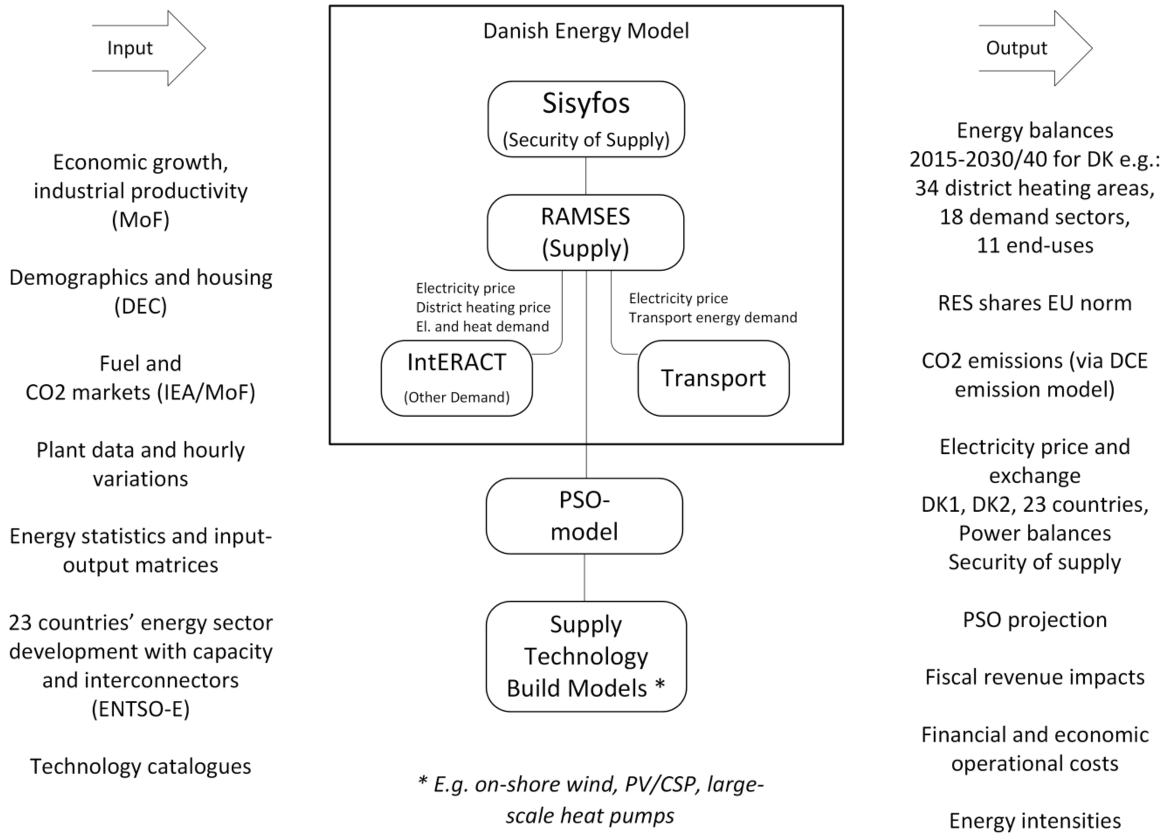
- The Transport Model models energy consumption in the transport sector. Amongst other things, the Transport Model is based on input from the Danish Transport, Construction and Housing Authority and uses the National Transport Model (LTM) (Technical University of Denmark, 2018) for data on developments in road traffic and energy consumption by railways. The Transport Model projects road transport based on projections for growth in transport 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. Energy consumption in air transport is projected based on developments in GDP, population numbers and expected developments in energy efficiency in aviation.

- The PSO model is used to calculate expected future expenditure on subsidies for electricity production. The model calculates expenses for offshore wind, onshore wind, biogas, photovoltaics, CHP production and more. The results are used to determine the PSO tariff and furthermore used 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 example for photovoltaic solar modules, onshore wind and large heat pumps, 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.

The system analyses by the Danish Energy Agency are used to model emissions of greenhouse gases for fuel consumption and non-energy-related activities on the basis of an emissions model and results provided by the Danish Centre for Environment and Energy, Aarhus University (Aarhus University, 2018). Non-energy activities include, for example, agriculture as well as waste management, wastewater treatment and industrial processes.

Figure 2: The Danish Energy Agency's integrated model platform for energy and climate (greenhouse gas emissions). See the Danish Energy Agency website for descriptions and documentation of the sub models (Danish Energy Agency, 2018c).



1.6 Why are some results adjusted for electricity trade with other countries?

The results in DECO18 align with statistical principles and standards. This means that gross energy consumption and total greenhouse gas emissions are adjusted for annual net exchanges of electricity with other countries. Other results, such as shares of renewables, are based on calculated observed (actual) energy consumption.

This adjustment is made to ensure that calculations of total gross energy consumption and greenhouse gas emissions reflect the actual interrelated system impacts of developments in Danish energy consumption.

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. 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.[3] The Danish Energy Agency's method for statistical computation of the adjustment of net-exchange of electricity with other countries is updated regularly to reflect ongoing changes in the energy system (Danish Energy Agency, 2016).[4]

Statistical years (<= 2016) can, moreover, have been adjusted for fluctuations in temperature (climate-adjusted) relative to a statistically determined normal year. However, the DECO18 always calculates on the basis of normal years.

1.7 Managing sensitivities and uncertainties

DECO18 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 initiatives and on the basis of current knowledge.

It is crucial that the projection is read and used with awareness that sensitive assumptions and uncertainties affect the key results.

A number of especially sensitive assumptions have been identified for the purpose of partial sensitivity analyses, for example assumptions on the electricity consumption of data centres and on trends in fossil fuel prices. ‘Partial’ in this context means that a sensitivity analysis will be made for each sensitivity parameter 'all else being equal'. The resulting sensitivity effects cannot readily be aggregated. The probability of the individual sensitivities' variation has not been assessed, nor has an overall risk analysis been performed.

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

1.8 Figures and tables as well as assumptions are available for download

Selected central assumptions are included in the form of a memorandum about assumptions (Danish Energy Agency, 2018b).

Figures and tables are included in the form of a spreadsheet (Danish Energy Agency, 2018a).

The memorandum on assumptions and the figures and tables can be downloaded at the website of the Danish Energy Agency, 2018f. Both documents are only available in Danish.

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[3] In this context, thermal electricity production plants cover electricity production from coal, natural gas, oil and solid biomass (wood pellets and wood chips).

[4] The DECO18's model platform can be used as the basis for calculating the energy and emissions impacts of Danish cross-border electricity exchange in an interlinked European energy system on an hourly basis. The result aggregated to an annual basis corresponds, in principle, to the statistical calculation method, which, however, assumes that there are no technical limitations to electricity exchange.

2 The overall picture

- The total share of renewables (RES) is expected to be 39.8% in 2030 in the absence of any new initiatives, which results in a shortfall of 10.2 percentage points relative to the goal in the Government's Political Platform of at least 50% renewables in 2030. The renewables share will increase up to 2021 to 43.6%, followed by a decline due to increased electricity consumption and a decline in the deployment of renewable energy. The renewables share is expected to be 42.0% in 2020, whereby Denmark will have met, and exceeded, its EU obligation for a 30% renewables share by 2020.

- In 2020, Denmark's total greenhouse gas emissions are expected to be 38-39% below emissions in the UN baseline year of 1990. Up to 2021, emissions will fall to 39% below the UN baseline year. After 2021, emissions are expected to increase in the absence of any new initiatives. This trend is contingent on the level of energy-related emissions in particular. The EU obligation for the non-ETS sector for the period 2013 to 2020 will be fulfilled and exceeded. Non-ETS emissions for the period 2021-2030 are expected to fall short of the EU obligation by between 32 to 37 million tonnes CO_2-eq., subject to an uncertainty of +/- 10 million tonnes CO_2-eq.

- Electricity consumption (exclusive of grid losses) will increase from 31.3 TWh in 2017 to 42.2 TWh in 2030. This increase depends in particular on increased electricity consumption by data centres, which will account for 65% of the increase and are expected to account for 16.7% of total electricity consumption (exclusive of grid losses) in 2030. Future demand for electricity by data centres is subject to significant uncertainty. Increasing electricity demand in combination with new electricity interconnectors to high-price areas means that domestic electricity production will increase up to 2023, and that Denmark is expected to be a net exporter of electricity from 2020 to 2024. After this time, electricity imports will increase in light of declining deployment of new domestic capacity, and, assuming no new initiatives are introduced, net imports are expected to amount to 8.6 TWh in 2030, corresponding to 19% of electricity consumption (including grid losses).

- The share of electrified vehicles (electric cars and plug-in hybrid cars) is expected to increase steadily, and will account for 7% of the total number of cars and vans on the road in 2030 as well as for 1.2% of electricity consumption (excluding grid losses). Electrified vehicles' share of sales of new cars up to 2030 is subject to significant uncertainty. The 10% renewables obligation in transport by 2020 will not be achieved in the absence of new initiatives.

- Consumption of bioenergy will be constant from 2021, but with a share of 67% in 2030 it is expected to still make up the majority of renewable energy consumption. Consumption of renewable energy in the form of ambient heat by large and small heat pumps will increase by 7.3% annually and will account for 8% of renewable energy consumption in 2030. Heat pumps will increasingly displace the use of wood pellets, natural gas and oil by households. In 2030, oil for heating will account for less than 2% of household energy consumption.

- In the absence of any new initiatives, energy consumption in industry and services will fall by

0.4% annually up to 2020, after which it is expected to increase by 2.2% annually up to 2030 due to an increase in electricity consumed by data centres and the discontinuation in 2021 of the scheme concerning the energy saving efforts of energy companies.

- Uncertainties and assumptions subject to sensitivity affect the key results. For example, there is uncertainty associated with the projection of electricity consumption by data centres, as well as with assumptions about the CO2 allowance price, fossil fuel prices, transport volume, number of dairy cattle, decommissioning of coal-fired electricity production capacity, and the distribution of vehicle types in sales of new cars.

2.1 Increase in renewables up to 2021 followed by a decline

Figure 3 shows the total share of renewables (RES) as well as renewables shares for transport (RES-T) and electricity consumption (RES-E), respectively, calculated on the basis of the method described in the EU Renewable Energy Directive (EU, 2009b; 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 total share of renewables (RES) will increase up to 2021, ending at 43.6%, after which time it will decline. Developments up to 2021 depend on the deployment of onshore and offshore wind, transition to biomass and energy-efficiency improvements in industry, services, and households.

Developments after 2021 will depend on the growth in electricity consumption, a decline in domestic renewables deployment and a decline in energy-efficiency improvements. The renewables share is expected to be 42.0% in 2020, whereby Denmark will have met, and exceeded, its EU obligation for a 30% renewables share by 2020.

The renewables share is expected to be 39.8% in 2030 in the absence of any new initiatives. The Government's Political Platform includes a target of at least 50% renewables by 2030. The analysis indicates that there will be a 10.2-percentage-point shortfall towards meeting this target.

The EU Renewable Energy Directive also sets out a 2030 target for 27% renewables for the EU as a whole, but this target has not been implemented as national obligations. Instead, from 2018, EU Member States are obliged to account for their contributions to reaching the common EU target in their National Energy and Climate Plans.

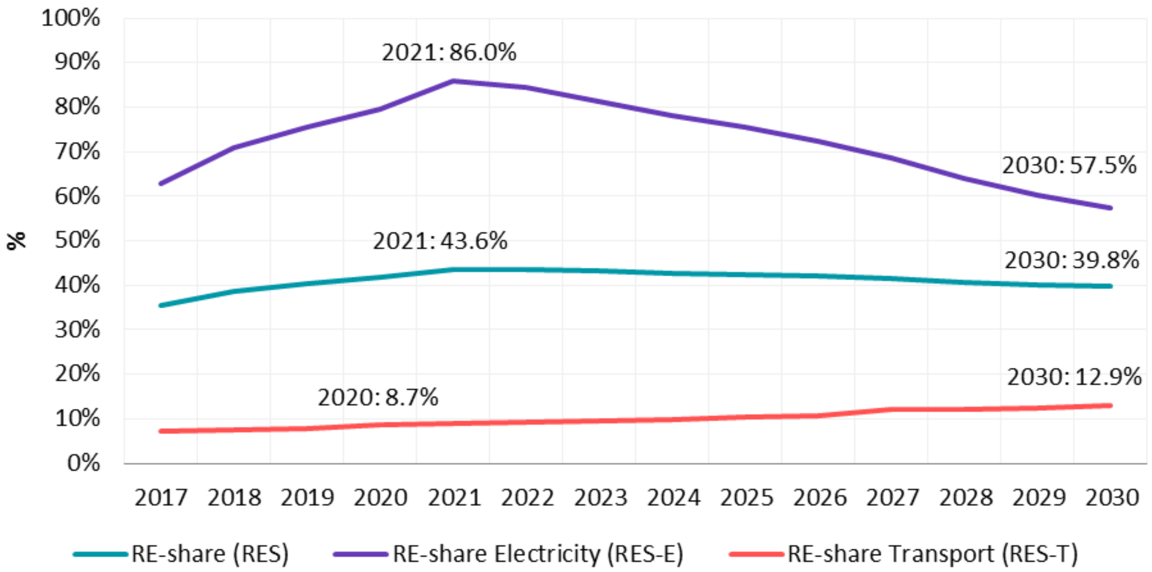
The share of renewables for transport (RES-T) will amount to 8.7% in 2020 and will increase steadily to 12.9% in 2030. The EU Renewable Energy Directive sets out a binding national target of 10% renewables in transport by 2020. The projections reveal a shortfall of 1.3 percentage points towards meeting this obligation. This development depends on an increase in transport volume, a slight increase in the blending ratio for biofuels in petrol and diesel fuel, a slight increase in the use of biogas in transport, and a steady rise in the use of electricity in road and railway transport.

The renewables share in electricity consumption (RES-E) will come to 86% in 2021 but will then decline, ending at 57.5% in 2030. The development after 2021 depends on increased electricity consumption and declining renewable energy consumption in domestic electricity production.

Fuel consumption for domestic as well as international air traffic is included in the calculation of the total renewables share (RES) and the renewables share for transport (RES-T). The aviation sector has announced ambitious plans for biofuel blending, but these announcements are not assessed to be binding, nor are they assessed to reflect a profitable development pathway for companies in the absence of any new initiatives.

The analysis shows that, in the absence of any new initiatives, the renewables share is expected to be 39.8% in 2030. This leaves a shortfall of 10.2 percentage points towards meeting the goal in the Government's Political Platform of at least 50% renewables. The renewables share will increase to 43.6% in 2021 but will then decline in the absence of any new initiatives. The renewables share will exceed the obligation in the Renewable Energy Directive in 2020. The renewables share for transport in 2020 will be 1.3 percentage points short of meeting the obligation in the Renewable Energy Directive.

Figure 3: Renewables shares 2017-2030 (RES, RES-E, RES-T) [%]. Renewables shares calculated on the basis of the EU standard in the Renewable Energy Directive (Eurostat, 2018).



2.2 Total greenhouse gas emissions will fall up to 2021

Since 1990, which is the UN's baseline year for calculating climate efforts, total annual emissions have fallen from 70.8 million tonnes to 53.5 million tonnes in 2016, corresponding to a reduction of 24%. This trend is expected to continue up to 2021, when annual emissions will have been reduced by 39% relative to the 1990 baseline-year level.

In the absence of any new initiatives, increasing electricity demand and a decline in deployment of renewables will give rise to an increase in consumption of fossil fuels after 2021, which, in turn, will lead to an increase in energy-related emissions. Total emissions will increase from 43 million tonnes in 2021 to 51-52 million tonnes in 2030.

The analysis shows that, in the absence of any new initiatives, total greenhouse gas emissions will be reduced by 39% in 2021 relative to the 1990 baseline year but, after this point, emissions will increase.

2.3 Achievement of non-ETS reduction targets 2021-2030 will fall short by 32-37 million tonnes CO2-eq.

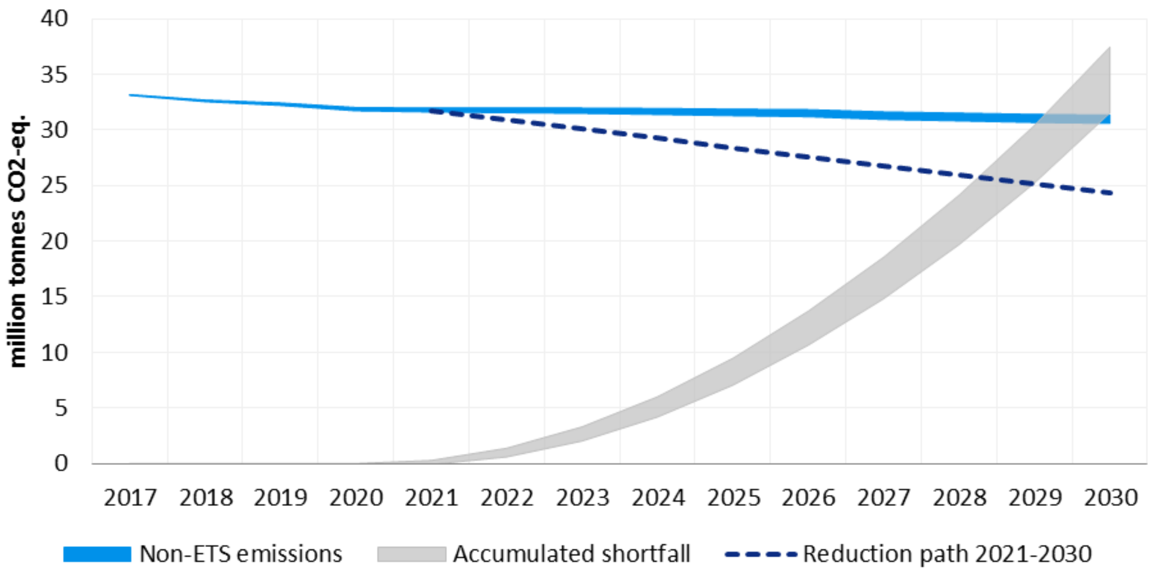
Denmark has committed to reducing emissions from non-ETS sectors by 39% by 2030 relative to the 2005 level (European Commission, 2014, 2017a).

Figure 4 shows that emissions are expected to exceed the annual targets in all years throughout the period 2021-2030. The accumulated shortfall is calculated at 32-37 million tonnes CO2-eq. in 2030. The sensitivity calculations in Chapter 8 moreover suggest that emissions may vary by +/- 10 million tonnes CO2-eq. Emissions in 2030 will fall to a range around 31 million tonnes CO2-eq., corresponding to a reduction of 21%-23% compared to 2005.

The range reflects the uncertainty associated with assumptions about the observed (actual) energy consumption of vehicles, see Chapter 8.4. This uncertainty means that the accumulated emissions from 2021 to 2030 vary from 312 to 318 million tonnes of CO2-eq., corresponding to 1.9%. Despite the slight variation, the effect of this slight uncertainty will accumulate over the ten-year period resulting in a more prominent variation when calculating the shortfall.

The analysis shows that, for the period 2021-2030, non-ETS emissions are expected to fall short of the EU obligation by between 32 and 37 million tonnes CO2-eq., subject to an uncertainty of +/- 10 million tonnes CO2-eq.

Figure 4: Non-ETS emissions 2017-2030, as well as the reduction commitment and accumulated shortfall 2021-2030 [mill. tonnes CO2-eq.].



2.4 The introduction of data centres will lead to increased demand for electricity

The demand for electricity and its composition will change up to 2030, depending, in particular, on the expected electricity consumption of data centres (Text box 1) and electrification initiatives within heating and transport.

Figure 5 illustrates that electricity consumption (excluding grid losses) will increase by 1.2% annually up to 2021 and then increase by 2.8% annually up to 2030, corresponding to an increase rate of 2.3% over the period 2017-2030.

The increased electricity demand will depend, in particular, on an increased demand for electricity at data centres that will be introduced in 2019, as Facebook will put into operation a data centre in Odense and Apple a data centre in Viborg. Furthermore, Google has purchased a property for a similar purpose in Aabenraa. COWI A/S has assessed the deployment of data centres in upcoming years on behalf of the Danish Energy Agency (COWI A/S for the Danish Energy Agency, 2018). On the basis of the assessment, this report presents a number of development pathways. DECO18 assumes COWI's central development pathway, which results in an expectation that the demand for electricity at data centres will increase from 2019 onwards to 7.0 TWh in 2030.

Text box 1: Data centres in the projections (COWI A/S for the Danish Energy Agency, 2018).

Data centres are large facilities with computer servers that supply data services for the entire world through data connections. Data centres require a location with access to optical fiber connections and electricity supply. Large data centres are established for international IT businesses in order to supply software and services or server space for several co-owners.

On behalf of the Danish Energy Agency, COWI A/S has developed a methodology for the projection of electricity consumption at data centres in Denmark based on factors that drive the deployment of data centres internationally(COWI A/S for the Danish Energy Agency, 2018). The methodology is underpinned by an assessment of the total deployment of data centres in Europe and an assessment of the share of data centres that will be built in Denmark. On the basis of these assessments, deployment in Denmark is expected to total 900 MW with an expected consumption of 7 TWh in 2030. This could be in the form of, for example, 6 data centres with an average capacity of 150 MW.

Electricity consumption for heating and transport will increase overall by 5.7% annually over the period, which reflects, in particular, electrification of the heating sector (heat pumps and electric boilers) and of rail transport. Electricity consumption for heating in households and for district heating is expected to increase by 3.9% annually, while electricity consumption for rail transport will increase by 7.7% annually.

A total of 700 electric cars and 621 plug-in hybrid cars were sold in 2017. This corresponds to 0.5% of the total sales of cars and vans, which totalled 258,000 (De Danske Bilimportører, 2018). Sales of electric cars and plug-in hybrid cars are expected to increase steadily to sales of 58,000 cars annually in 2030, corresponding to 22% of annual car sales. Based on this, electric cars and plug-in hybrid cars are expected to account for 7% of the total number of cars on Danish roads in 2030, which means that electricity consumption for electric road transport will be 0.5 TWh in 2030. Electrified vehicles' share of sales of new cars up to 2030 is subject to significant uncertainty.

Figure 6 shows electricity consumption by use in 2030. It can be seen from the figure that data centres are expected to account for 16.7% of total electricity consumption (excluding grid losses), while electricity consumption for heating in households and for district heating is expected to account for 6.4% of total electricity consumption (excluding grid losses). Electricity consumption for rail transport will account for 2.7% of total electricity consumption (excluding grid losses) in 2030, while electricity consumption for electric cars and plug-in hybrid cars is expected to account for only 1.2% of total electricity consumption, which suggests that uncertainty about future sales of electric cars and plug-in hybrid cars will be of minor significance for total electricity consumption in 2030.

The consequence of significant uncertainties about the electricity consumption of data centres and the share of electrified vehicles in sales of new cars up to 2030 is addressed in Chapter 8.

The analysis shows that electricity consumption is expected to increase significantly from 2021 due in particular to increased electricity consumption at data centres and increased electricity consumption for heating. There is uncertainty associated in particular with the projection of the electricity consumption of data centres and the share of electrified vehicles in sales of new cars up to 2030. Uncertainty about future sales of electric cars and plug-in hybrid cars is expected to be of less significance for total electricity consumption in 2030.

Figure 5: Electricity consumption (excluding grid losses) by use 2017-2030 (TWh).

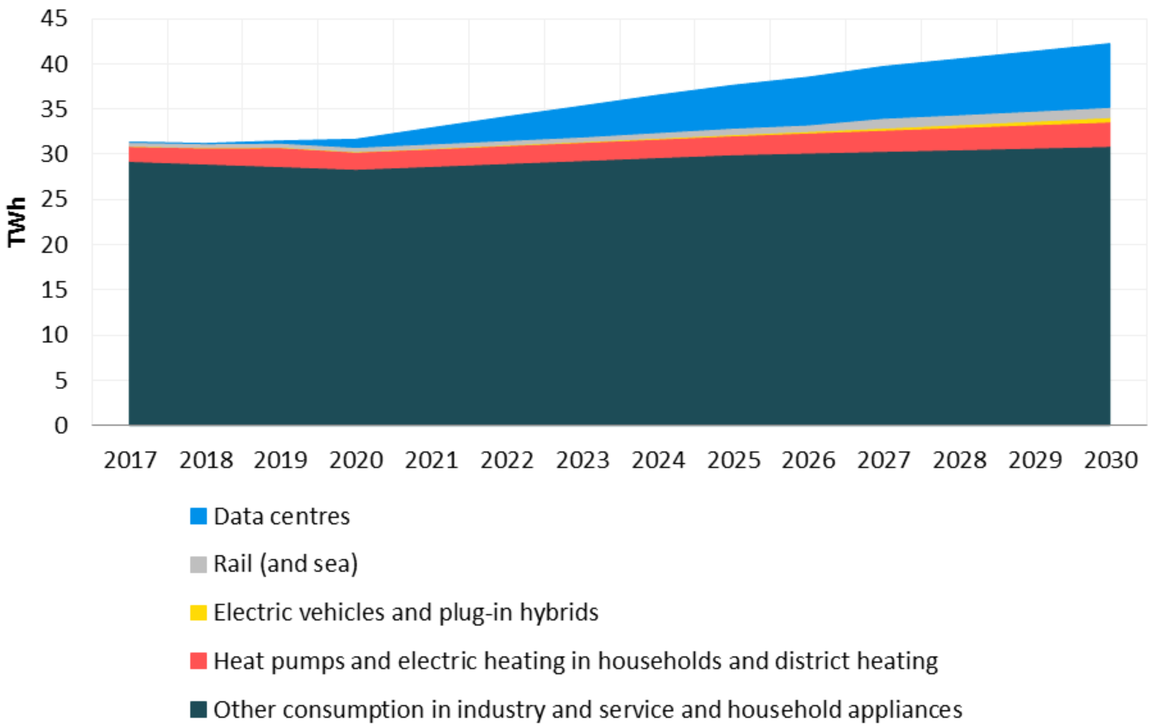
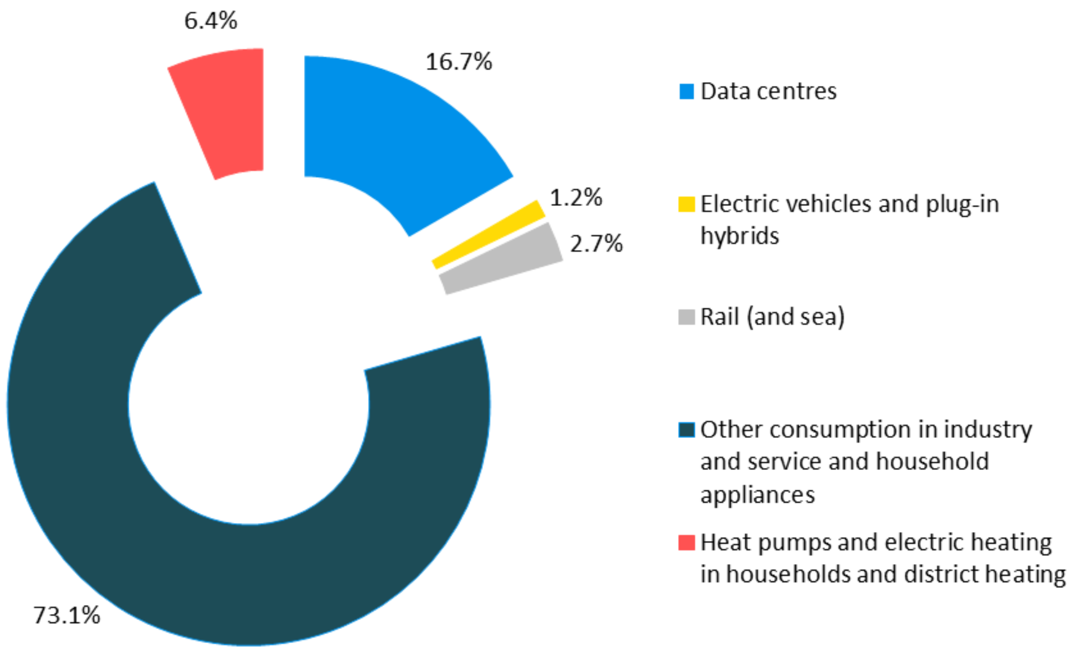


Figure 6: Electricity consumption (excluding grid losses) by use in 2030 [%].



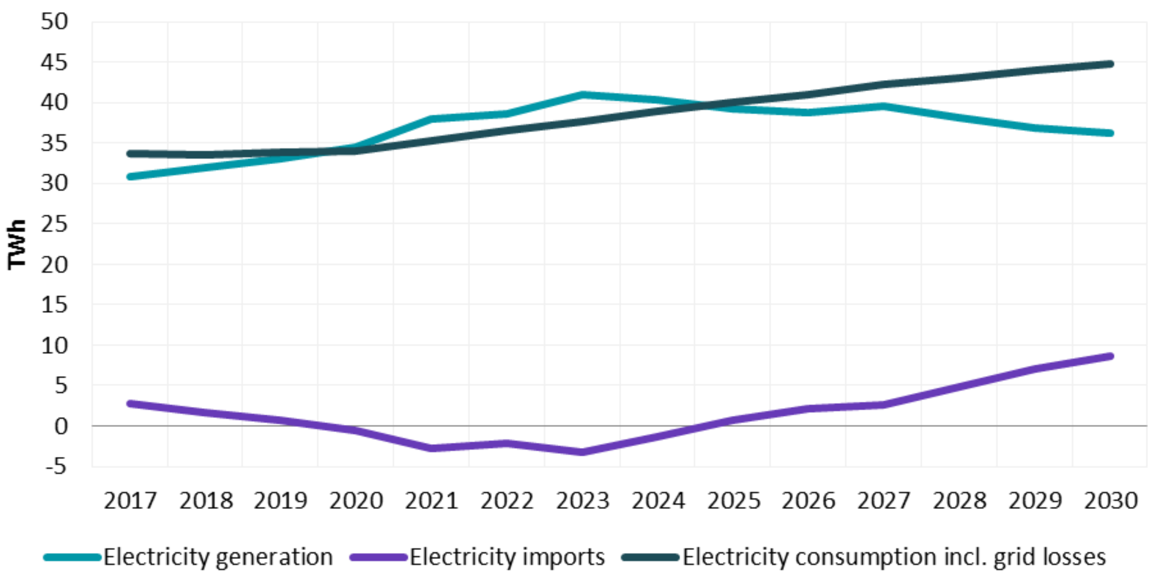
2.5 Domestic electricity production will increase up to 2023 but will then decline

Figure 6 shows that the increase in electricity consumption will be offset by an increase in domestic electricity production up to 2023. The increase in domestic electricity production will be 4.3% annually up to 2023. This depends, in particular, on deployment of wind power, and on Denmark's possibilities 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 a net exporter of electricity in the period from 2020 to 2024.

Despite increasing consumption and increasing exports, domestic electricity production will decline after 2023, although this depends, in particular, on a cease of wind power deployment after phasing in Kriegers Flak offshore wind farm in 2021/22. It is expected that Denmark will be a net importer of electricity from 2025 in the absence of any new initiatives. Net imports will account for 19% of total electricity consumption (including grid losses) in 2030.

The analysis shows that an increase in electricity consumption from 2024 is expected to be met by an increase in electricity imports in the absence of any new initiatives.

Figure 7: Electricity consumption (excluding grid losses), electricity production and electricity imports 2017-2030 (TWh).



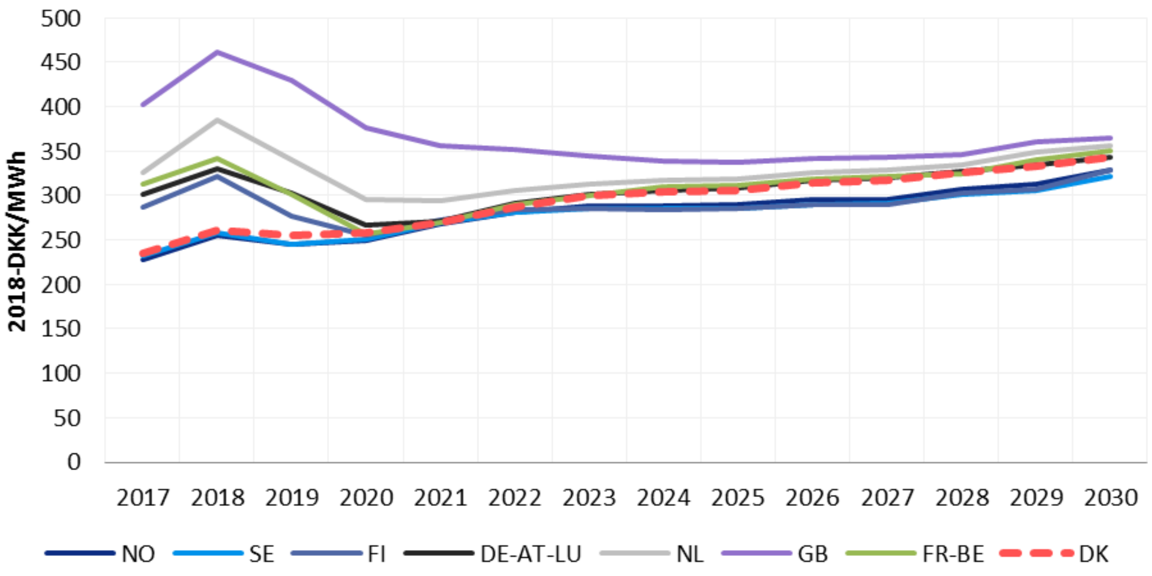
2.6 Interconnectors will reduce price differences

Denmark has considerable electricity exchange with its neighbouring countries and has the largest interconnector capacity in the EU relative to electricity consumption. The competitive situation between Denmark and other countries with regard to electricity supply is determining for the scope and direction of cross-border electricity exchange.

Figure 8 illustrates that the Nordic price zone is expected to converge towards a common continental western European price zone up to 2020. From 2023, Denmark's electricity prices are likely to move slightly behind prices in Germany, France and the Netherlands, whereas prices in the other Nordic countries will follow each other at a lower, parallel, level. Electricity prices in the United Kingdom start at a higher level and, up to 2030, will converge towards a continental western European price zone. The United Kingdom's relatively high price level depends, in particular, on the expectation that its minimum-price instrument for emission allowances (Carbon Price Floor) will lie at a level above the ETS allowance price level up to 2020, after which time it follow a linear phase-out curve up to 2030, which will contribute to gradually evening out the differences with other markets.

The analysis shows that, from 2023, Denmark's electricity prices are expected to move slightly behind prices in Germany, France and the Netherlands, whereas prices in the other Nordic countries will follow each other at a lower, parallel, level.

Figure 8: Electricity spot market prices for Denmark and selected price-setting markets 2017-2030 [2018 DKK/MWh]. Prices for all the years are model results. The Danish Energy Agency's use of electricity price results is based on statistical prices and forward prices for 2017-2019. See the DECO18 memorandum on assumptions (Danish Energy Agency, 2018b).



2.7 Consumption of renewables will increase, then even out and decline

Observed (actual) consumption of renewable energy will increase up to 2021, and this is particularly due to deployment of wind power, increased consumption of bioenergy and increased renewables contributions from heat pumps (ambient heat). Consumption of renewable energy will increase by 4% annually up to 2021 but will subsequently even out and decline.

Figure 9 shows observed renewable energy consumption by type of energy. Bioenergy's share of consumption will fall from 72% to 67% from 2017 to 2030. Amongst other things, this development depends on an increase in consumption of wind power of 9% annually up to 2022, an increase in the renewables contribution from heat pumps (ambient heat) of 7% annually throughout the period, while the consumption of bioenergy will level off from 2021.

The development in consumption of wind power reflects net offshore and onshore wind power deployments of 1950 MW up to 2021/22. Of this, offshore wind farms will account for 1366 MW (Kriegers Flak, Horns Rev 3, Vesterhav Nord/Syd), while onshore wind will account for 584 MW (net). Amongst other things, a total of 537 MW onshore wind power was commissioned in the period 2017-2018 as part of the onshore wind subsidy scheme that ended in February 2018.

Consumption of wind power will peak in 2022 when Kriegers Flak will have been fully phased in. However, after this time, consumption will decline by 3% annually due to decommissioning of older turbines. No deployment of wind power is expected from 2023 in the absence of any new initiatives.

The development in consumption of ambient heat reflects an expected increase in the use of heat pumps for space heating purposes in the district heating sector, by households, and in industry and services. This development depends on the expected effect of the agreed reductions in the tax on electricity of DKK 0.15/kWh in 2019[5], DKK 0.20/kWh in 2020, and DKK 0.10/kWh from 2021 and onwards, in combination with the approved conversion of the PSO tariff and its discontinuation from 2022. This means a 30% reduction in the tax on electricity for heating purposes in 2030 relative to 2017, in constant prices.

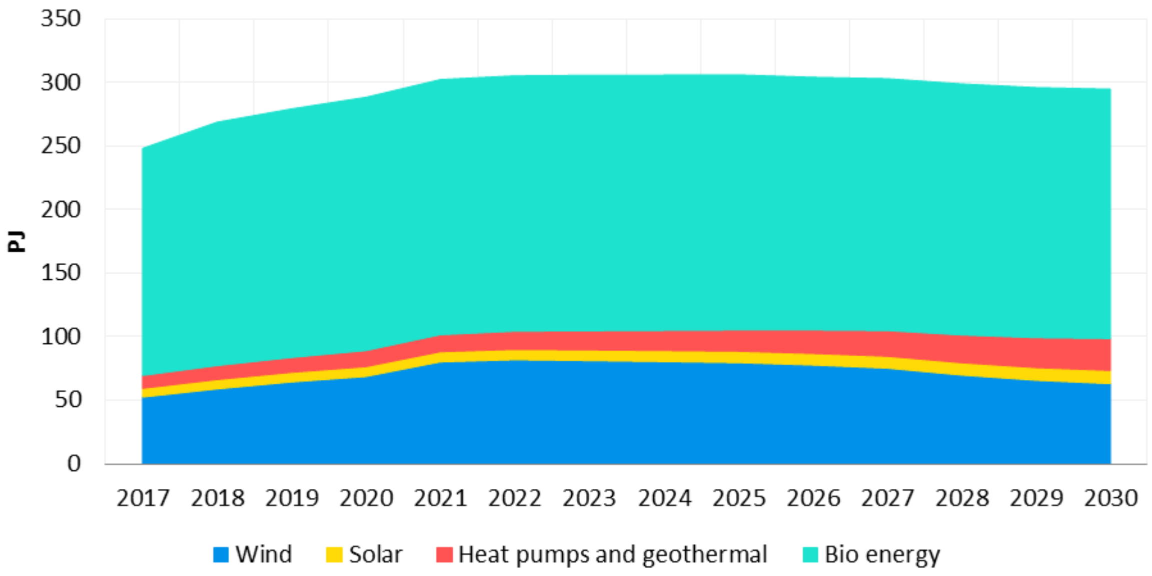
Consumption of solar energy for electricity and heating will increase by 3% annually. Amongst other things, this depends on the adjustment in 2017 of the terms and conditions for photovoltaic solar modules (transition to so-called 'instant settlement'), which will result in a slower pace of deployment than previously expected. Solar capacity is expected to increase from just over 900 MW to just over 1400 MW from 2017 to 2030. Deployment depends solely on technological developments and on the profitability of 'instant settlement', in that the analysis computationally assumes that the technology-neutral tendering procedure in 2018/19 will result in the deployment of new onshore wind capacity only.

Consumption of renewable energy by the transport sector will increase by 1% annually up to 2030. This depends on a combination of an increase in demand for transportation and biofuel blending in petrol and diesel fuel as well as the effect of increased electrification.

The analysis shows that consumption of renewable energy will increase up to 2022 and will then follow a downward trend, which depends, in particular, on a decrease in the deployment of wind power. Bioenergy will continue to account for the greatest share of renewable energy consumption. Ambient heat from heat pumps will account for an increasing share of renewable energy consumption.

[5] In February 2018, the Government concluded an agreement to bring forward the reduction of the tax on electric heating to 1 May 2018, whereas the DECO18 assumes this reduction will take effect from 1 January 2019 as originally planned.

Figure 9: Observed (actual) renewable energy consumption by main type 2017-2030 (PJ).



2.8 Gross energy consumption will increase again from 2021

Gross energy consumption[6] peaked in 2007 at 873 PJ but has since followed a downward trend. From an expected minimum of 718 PJ in 2020, gross energy consumption is expected to increase to 832 PJ in 2030, corresponding to an annual increase rate of 0.9%. GDP is expected to grow by 1.5% annually over the same period.

The fall in gross energy consumption from 2017 to 2020 depends, in particular, on continued efficiency improvements in energy consumption and on continued wind power deployment. [7]

Coal consumption will fall by almost 10% annually up to 2021. Amongst other things, this depends on an expectation that coal-based electricity production will cease at Block 2 at Asnæsværket from 2021 and at Block 3 at Amagerværket from 2020, and that it will be temporarily discontinued at Block 4 at Studstrupværket and Block 5 at Asnæsværket in 2019. Remaining coal-based electricity generating units, including Nordjyllandsværket in Aalborg, are expected to continue in operation up to 2030.

The increase in gross energy consumption and coal consumption from 2020/21 is primarily due to the effect of increased electricity consumption at data centres. Gross energy consumption will also increase in the transport sector due to on an increase in the demand for transportation, and in the manufacturing industries due to economic growth, while gross energy consumption in households will continue to fall.

[6] Adjusted for electricity trade and, in statistical years, adjusted for fluctuations in temperature (climate-adjusted) relative to a normal year.

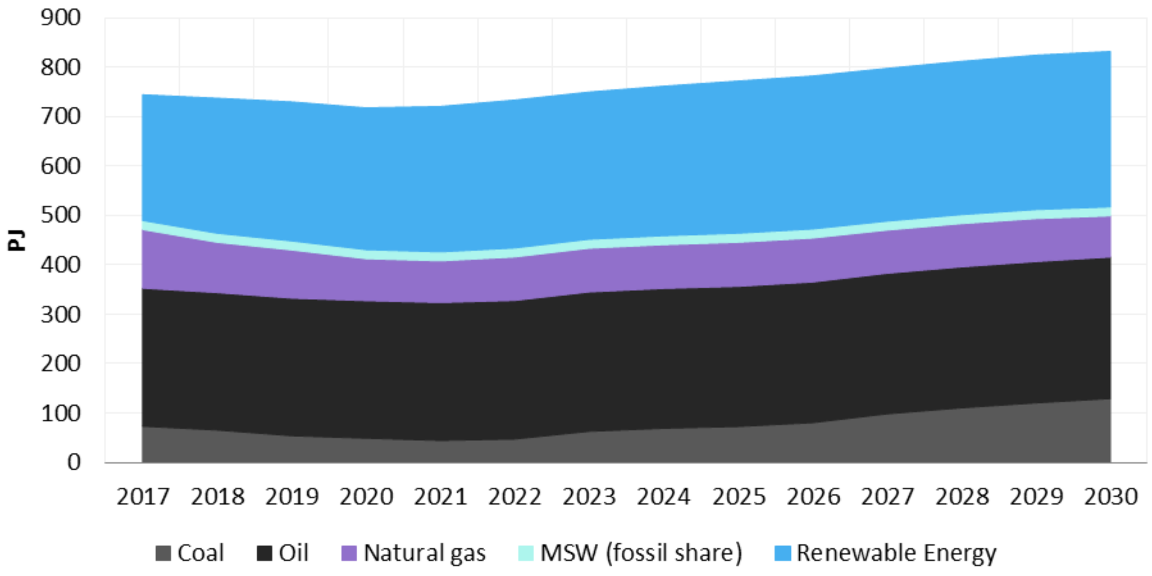
[7] Wind power deployment reduces conversion losses compared with thermal electricity production, which contributes to lower gross energy consumption.

In the absence of any new initiatives, an increase in electricity consumption at data centres will contribute to an expectation that, from 2023, in particular, coal-based electricity production will again be economically profitable. This will lead to an increase in consumption of coal at units already in operation, but it will also result in operations at Block 4 at Studstrupværket and Block 5 at Asnæsværket being resumed in 2023 and 2027, respectively, following an economic profitability assessment. This is considered a highly likely development in the absence of any new initiatives.

A continued increase in electricity consumption and a general decline in domestic capacity deployment will result in an increase in net electricity imports from 2025, for which adjustments have been made in the calculation of gross energy consumption.[8] This gives rise to an adjusted consumption of fossil fuels and solid biomass. The resulting increase in coal consumption will be 12.5% annually from 2021 to 2030 in the absence of any new initiatives.

The analysis shows that gross energy consumption will increase again. The expected increase from 2021 is due, in particular, to an increase in electricity consumption at data centres, an increase in the demand for transportation, as well as on economic growth in the manufacturing industries. Consumption of coal can subsequently be expected to increase from 2023, in particular, in the absence of any new initiatives.

Figure 10: Gross energy consumption by type of energy 2017-2030 [PJ]. Gross energy consumption has been adjusted for electricity trade with other countries based on the method on thermal domestic average (coal, oil, gas, solid biomass).



[8] Gross energy consumption has been adjusted for net-exchange of electricity with other countries in accordance with statistical principles using the method on thermal domestic average, as described in Chapter 1.6.

2.9 Significant sensitivities and uncertainties

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

The analysis shows that uncertainty about a number of central assumptions, for example the electricity consumption of data centres, trends in fossil fuel prices, demand for transportation, and choice of vehicles in sales of new cars, can have a significant impact on key results in the projections. For example, it is assessed that non-ETS emissions may vary by around +/- 10 million tonnes CO2-eq. in the period 2021-2030.

3 Energy consumption in households

3.1 Main points

- Final energy consumption by households for heating purposes is expected to fall from 163 PJ to 150 PJ from 2017 to 2030, corresponding to 0.6% a year, despite an expected increase in the floor area of 0.6% a year over the period. This is due to an expected shift to more efficient heating technologies and continued energy improvement of buildings.

- Recent years' increase in the consumption of wood pellets is expected to subside and will again be less than the 2006 level from 2025. Electrical heat pumps in particular are expected to replace the use of wood pellets for heating.

- 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 1.8% annually. This is especially due to electrical appliances becoming increasingly more efficient as a result of the EU ECOdesign Directive.

3.2 The overall picture

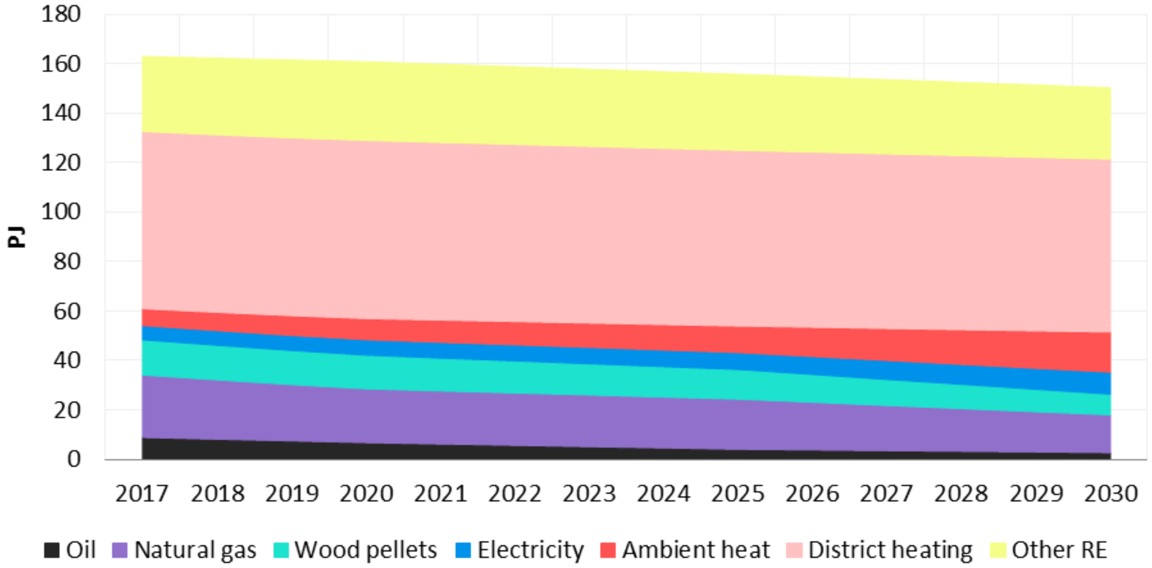
Final energy consumption by households was 31% of the total final energy consumption in 2017, and this is expected to fall to 27% in 2030. The share of energy consumption used for heating will be around 82% throughout the period. Other energy consumption by households will be used for electrical appliances.

Historically, oil consumption for heating fell from 22% in 2000 to 6% in 2017. In the period up to 2003, especially households shifted to natural gas, but from 2004 to wood pellets in particular. Figure 11 shows that the distribution of energy consumption by heating technologies is still changing. Up to 2030, wood pellet consumption is expected to fall by 4.0% annually, whereas consumption of oil and natural gas will fall annually by 8.6% and 3.8%, respectively. The falling consumption of wood pellets and fossil fuels will be offset by an increasing consumption of electricity and ambient heat, which together will increase by 6.9% annually. Consumption of district heating and other renewable energy, primarily consisting of firewood, will remain unchanged for the period.

Despite an increasing 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 following the EU ECOdesign Directive and the Energy Labelling Directive. Electricity consumption for appliances is expected to increase by 0.3% annually up to 2030.

The analysis points to the decreasing costs for electrical heat pumps, which will replace fossil fuels and wood pellets for heating, as well as the use of more, but also more efficient, electrical appliances.

Figure 11: Final energy consumption by households for heating 2017-2030 [PJ]. Other RE includes firewood in particular, but also solar heating, straw, wood chips, and biogas.



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 from 163 PJ to 150 PJ from 2017 to 2030, corresponding to 0.6% a year, despite an expected increase in the floor area of 0.6% a year. The increase in heated floor area is particularly due to a net increase of around 11,775 homes a year (Zangenberg Hansen, Stephensen, & Borg Kristensen, 2013).

Net space heating demand is expected to fall from 141 PJ to 136 PJ from 2017-2030. This fall will be due to higher standards of insulation in new buildings and insulation of existing buildings. This development is particularly conditional upon tighter building regulations and energy-savings efforts by energy companies up to 2020.

The analysis shows 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.

3.4 Electric heat pumps will replace wood pellets (as well as oil and natural gas)

Up to 2030, electric heat pumps are expected to increasingly displace other heating technology. This depends in particular on the reduction of the tax on electricity agreed under the Agreement on Business and Entrepreneurial Initiatives in 2017: a reduction in the tax on electric heating by DKK 0.10/kWh plus an additional reduction of DKK 0.05/kWh in 2019, DKK 0.10/kWh in 2020, and an annual reduction in the PSO tariff up to 2021 and removal of the tariff from 2022.

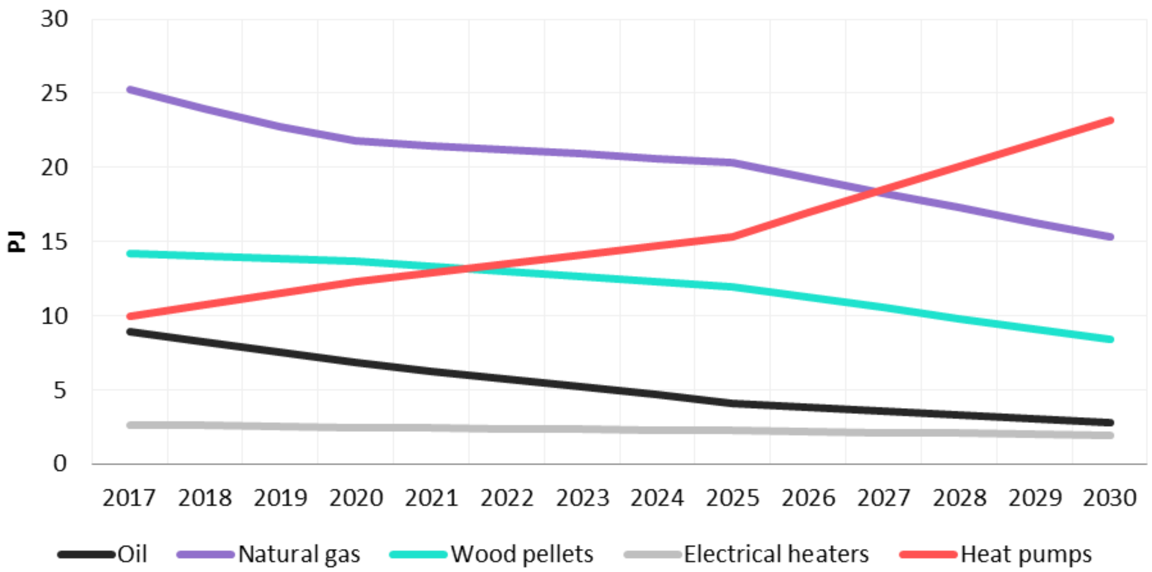
Figure 12 shows that consumption of oil, natural gas and wood pellets for heating is expected to fall up to 2030.

After several years of increases in consumption, consumption of wood pellets is expected to fall by 4.0% a year and will have fallen back to the consumption level of 2006 by 2030. Consumption of electricity for electric panels will fall by 2.4% annually.

Particularly heat pumps are expected to replace the consumption of fossil fuels and wood pellets for heating. Consumption of ambient heat and electricity for heat pumps will increase by 6.7% annually from 2017 to 2030. Consumption of ambient heat and electricity for heat pumps is expected to exceed consumption of wood pellets from 2022 and consumption of natural gas from 2027.

The analysis shows that heat pumps will replace wood pellets, oil and natural gas. In 2030, consumption of ambient heat and electricity for heat pumps will be equal to the total consumption of wood pellets and natural gas.

Figure 12: Final energy consumption by households analysed by selected heating technology 2017-2030 [PJ]. Energy consumption by heat pumps includes ambient heat and electricity consumption.

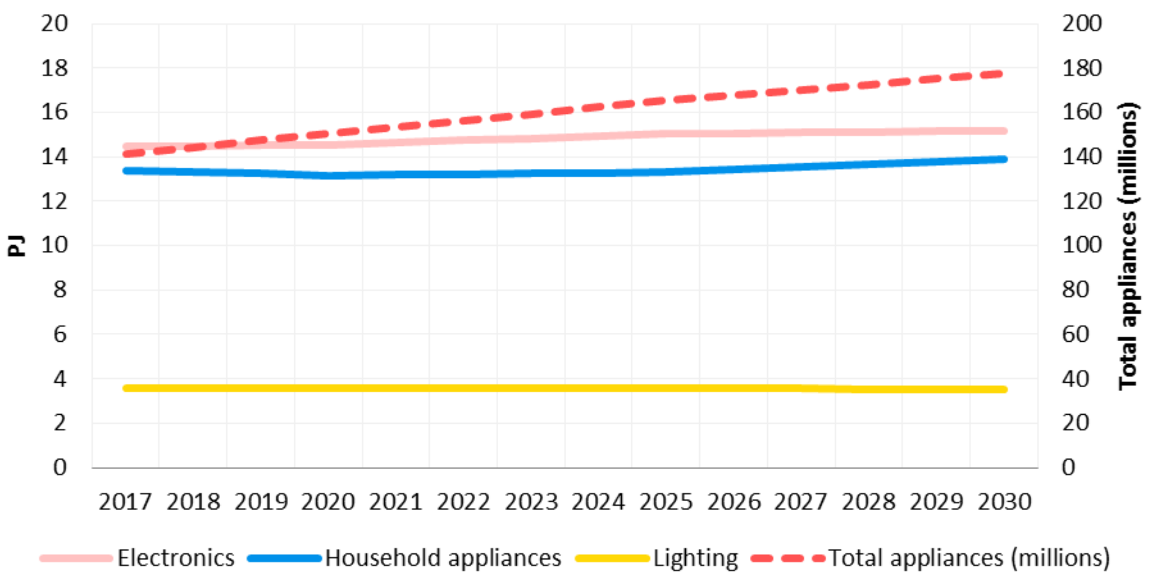


3.5 More, but also more efficient, electrical appliances in Danish homes

Due to growing private consumption, people will buy more electrical appliances. Figure 13 illustrates that the number of electrical appliances is expected to increase by 1.8% annually from 2017 to 2030. At the same time, the energy efficiency of these appliances will improve and more efficient appliances will be in demand. This depends on continuous tightening of EU minimum requirements for energy efficiency (ECOdesign requirements), EU energy labelling requirements, and a greater number of products being covered by these requirements. Consequently, electricity consumption for appliances is expected to increase from 32 PJ to 33 PJ from 2017-2030, corresponding to an annual increase rate of 0.3%.

The analysis points to 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 13: Number of electrical appliances [in mill.] and developments in electricity consumption by use: electronic equipment, electrical appliances, and lighting [PJ] 2017-2030.



3.6 Significant sensitivities and uncertainties

Assumptions regarding households' choice of heating technology are sensitive to fuel prices as well as to electricity and district heating prices. Moreover, assumptions about techno-economic developments for individual heating technologies have a significant impact, particularly with regard to heat pumps.

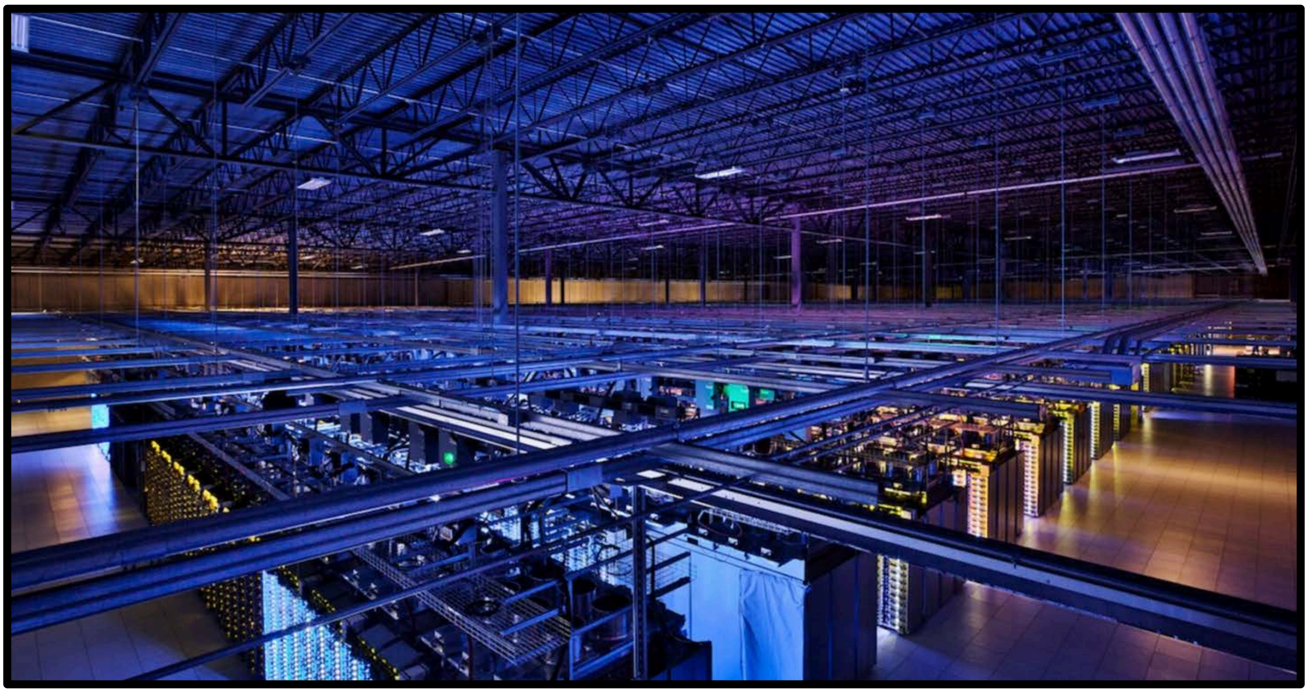
Possible consequences of significant sensitivities for key results are described in Chapter 8.

4 Energy consumption in industry and services

4.1 Main points

- Final energy consumption in industry and services will be constant at around 205 PJ up to 2020 and then increase to 254 PJ in 2030, corresponding to an annual increase rate of 1.6%.
- Electricity consumption will decline slightly up to 2020, but then increase significantly. Electricity consumption for new data centres will account for 85% of the increase in electricity consumption in industry and services from 2017 to 2030.
- Energy intensity of industry and services (without data centres) will fall up to 2020 and then stagnate in the absence of any new initiatives.
- The share of fossil fuels in energy consumption by the corporate sector will fall from 39% to 33% from 2017 to 2030. More than half of fossil fuel consumption by the corporate sector will be used for medium-temperature process heat.

Photo 1: Google data centre. Electricity consumption for new data centres will account for 85% of the increase in electricity consumption in industry and services from 2017 to 2030.



4.2 The overall picture

Energy consumption in industry and services will increase from 33% to 38% of total Danish final energy consumption from 2017-2030.

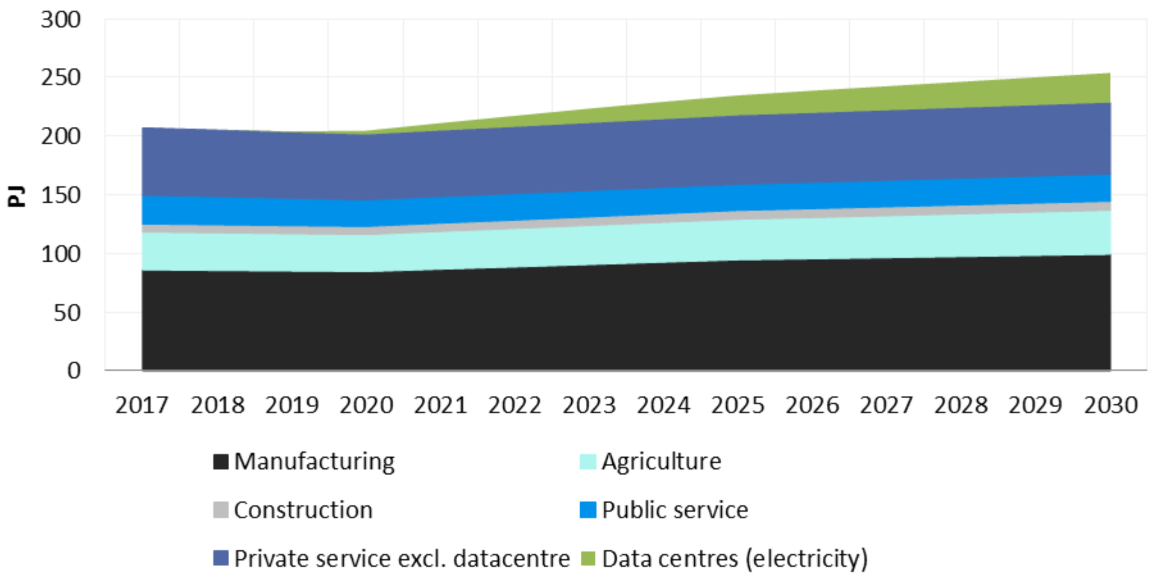
Figure 14 illustrates that energy consumption in industry and services will fall by 0.4% annually from 2017 to 2020, after which it is expected to increase by 2.2% annually up to 2030, corresponding to 1.6% a year from 2017-2030. The increase in energy consumption primarily depends on increasing electricity demand for 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 develop in line with economic growth, which is expected to be around 1.5% a year in the period.

Historically, energy consumption in industry and services has been characterised by continuous improvements in energy efficiency, and this is reflected in the fall in energy intensities. This development is expected to continue up to 2020, after which energy intensities is expected to stagnate in the absence of any new initiatives. This primarily depends on termination of the energy-saving scheme by energy companies by the end of 2020 (Danish Energy Agency, 2018e).

Final consumption of fossil fuels by the corporate sector will increase from 82 PJ to 85 PJ from 2017-2030, whereas the share of fossil fuels in final energy consumption will fall from 39% to 33%. More than half of the fossil fuel consumption in industry and services will be used for medium-temperature process heat i.e. temperature levels under 150°C.

The analysis shows that energy consumption in industry and services will increase from 2021. This depends on increasing electricity consumption by data centres and declining energy efficiency improvements in the absence of any new initiatives. More than half of fossil fuel consumption will be used for medium-temperature process heat.

Figure 14: Final energy consumption in industry and services analysed by sector 2017-2030 [PJ].



4.3 Energy consumption (particularly electricity consumption) will increase from 2021, mainly for the private sector

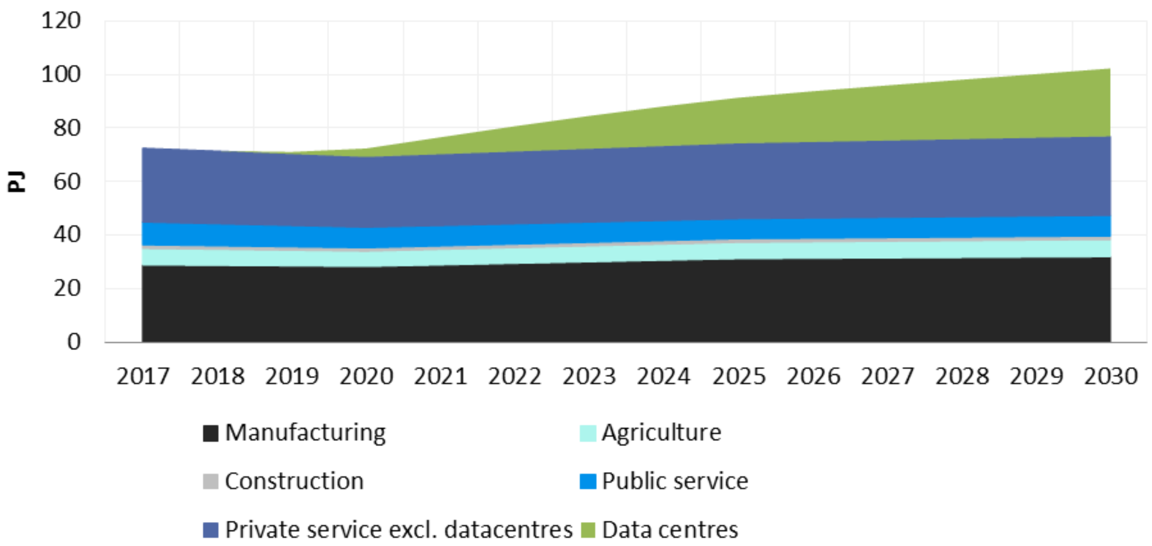
Figure 15 illustrates that energy consumption in industry and services will increase by 1.6% annually from 2017 to 2030. This increase will gain speed from 2021, and primarily depends on new and increasing electricity demand from data centres and termination of the energy-savings scheme by energy companies.

Energy consumption by the private service sector (including data centres) will, in relative terms, increase most by 3.2% annually. The private service sector's share (including data centres) of energy consumption in industry and services will increase from 28% to 34% from 2017 to 2030. Energy consumption by the manufacturing industries, agriculture and building and construction will increase by between 1.0% and 1.2% annually from 2017 to 2030.

This is particularly due to increasing electricity consumption. Figure 15 shows that electricity consumption in industry and services will increase from 73 PJ to 102 PJ from 2017 to 2030, corresponding to an annual increase rate of 2.7%. Data centres will account for 85% of the increase in electricity consumption. Energy consumption by manufacturing industries and agriculture will increase by 1.7% annually and 1.5% annually, respectively, from 2021, due to economic growth.

The analysis shows that the private service sector will account for an increasing share of final energy consumption in industry and services. This primarily depends on new and increasing electricity demand from data centres. Data centres will account for 85% of the increase in electricity consumption in industry and services.

Figure 15: Electricity consumption in industry and services analysed by sector 2017-2030 [PJ].



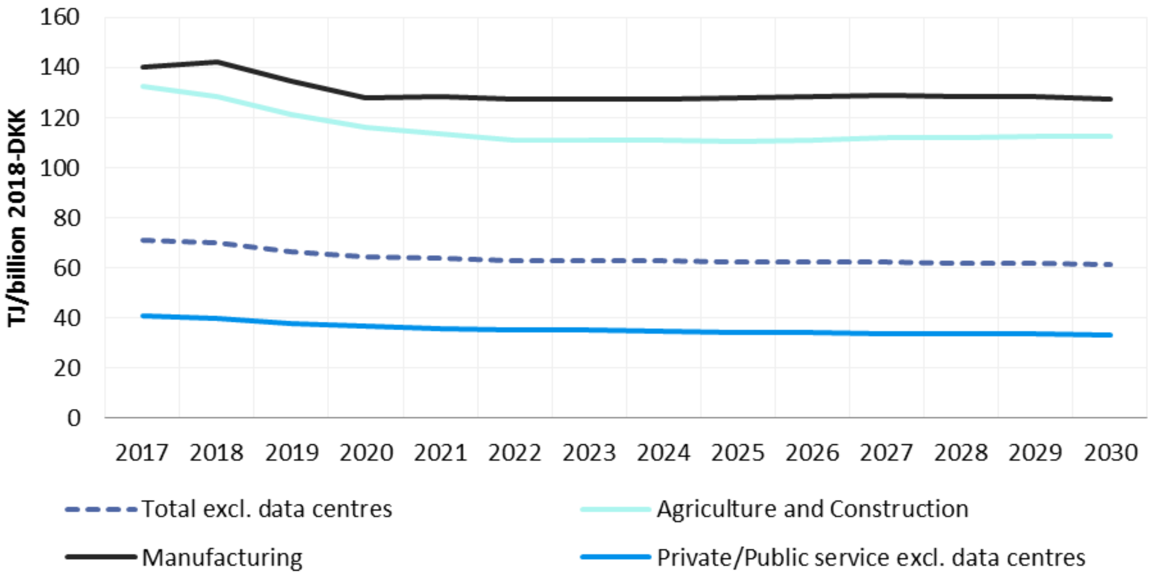
4.4 Energy intensity will fall up to 2020 and then stagnate

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 energy efficiency. The calculation of energy intensities does not include data centres, for which there is currently no estimate of the production value. [9]

Figure 16 shows the development in energy intensity analysed by sector. The figure shows that energy intensity will fall up to 2020 and then level off. Total energy intensity in industry and services will fall by around 3% annually from 2017-2020. From 2021, energy intensity will stagnate in the absence of any new initiatives.

The analysis shows that the energy intensity in industry and services will fall up to 2020 and then level off in the absence of new initiatives.

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



[9] Nor does the calculation include sea transport and energy production industries such as refineries. Neither production values nor energy consumption for these industries and the data centres are included in the calculation of energy intensities.

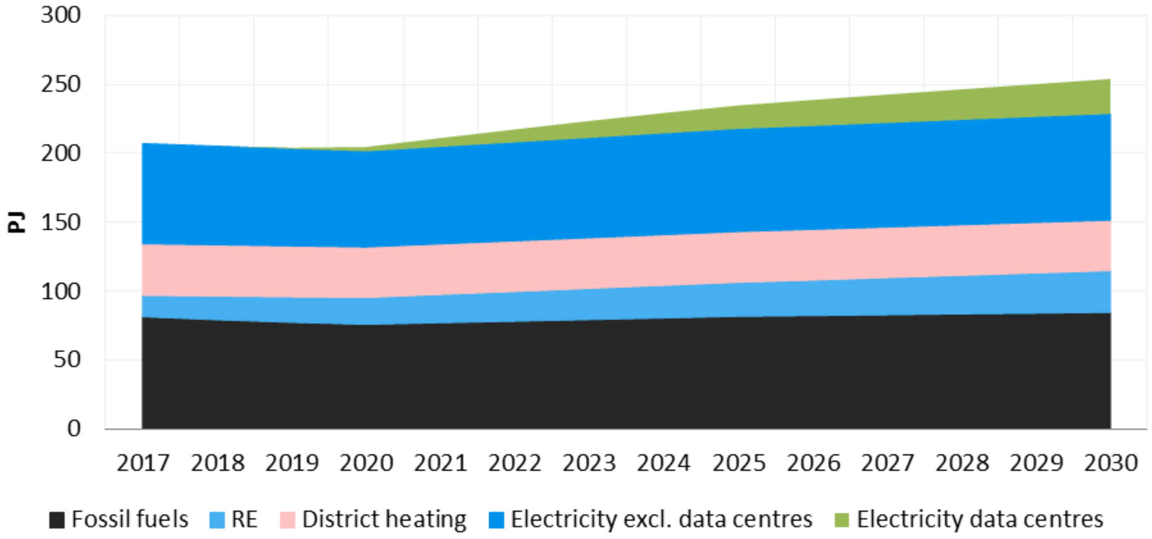
4.5 Fossil fuel consumption will increase again from 2020

Figure 17 shows the development in final energy consumption in industry and services analysed by type of energy from 2017 to 2030.

Fossil fuel consumption in industry and services will fall by 2.3% annually to 2020 and then increase by 1.1% annually up to 2030. Especially consumption of natural gas will fall up to 2020. Waste consumption (fossil fuel share) will be constant in the period.

The analysis shows that fossil fuel consumption in industry and services will fall up to 2020 and then increase in the absence of any new initiatives. Especially consumption of natural gas will fall up to 2020.

Figure 17. Final energy consumption in industry and services by type of energy 2017-2030 [PJ].



4.6 Fossil fuels will be used primarily for medium temperature process heat

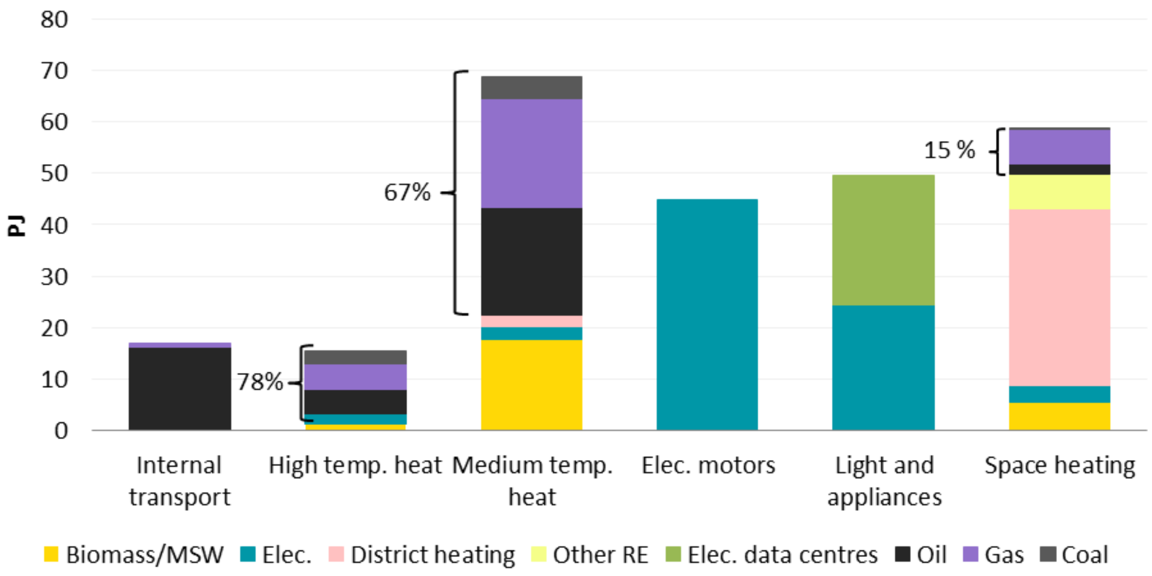
Figure 18 shows energy consumption by type of energy and end-use in 2030. The figure shows that industry and services will use fossil fuels for internal transport and process heat in particular.

Fossil fuel consumption will account for 78% of energy consumption for high-temperature process heat (more than 150°C) and 67% of energy consumption for medium-temperature process heat (less than 150°C). 15% of the energy consumption will be used for space heating.

More than half of the fossil fuel consumption will thus be used for medium-temperature process heat in 2030 in the absence of any new initiatives.

The analysis shows that the majority of fossil fuel consumption in industry and services will be used for medium-temperature process heat in 2030 in the absence of any new initiatives.

Figure 18: Final energy consumption in industry and services by type of energy and by end-use in 2030 [PJ]. [%] denotes total fossil fuel use.



4.7 Significant sensitivities and uncertainties

The projections of energy consumption in industry and services are sensitive to economic growth, which is an exogenous assumption. Moreover, the projections are particularly sensitive to assumptions regarding electricity consumption for data centres.

Technology choices and fuel use by the industries primarily depend on assumptions regarding technology costs and fuel prices. The projections are also sensitive to assumptions regarding the effect of the energy-saving scheme by energy companies up to 2020.

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

5 Energy consumption in transportation

5.1 Main points

- Final energy consumption in transportation will increase from 215 PJ to 228 PJ from 2017 to 2030, corresponding to 0.5% annually.

- Sales of electrified vehicles are expected to increase steadily and will account for 7% of the total number of cars and vans on the road in 2030. Electrified vehicles' share of sales of new cars up to 2030 is subject to significant uncertainty.

- The share of fossil fuels in energy consumption in transportation will fall from 95% in 2017 to 93% in 2030.

5.2 The overall picture

In 2017, energy consumption in transportation accounted for 34% of Danish energy consumption. The share of fossil fuels in energy consumption will fall from 95% in 2017 to 93% in 2030.

Up to the financial crisis in 2008, energy consumption in transportation had been increasing steadily. The financial crisis and greater focus on the energy efficiency of cars resulted in a fall in energy consumption up to 2013. After this, energy consumption by road transport has followed an upward curve again, due in particular to an increase in the number of vehicles, which reflects an increase in sales of small petrol cars and medium-sized diesel cars. This has also meant an increase in the number of kilometres driven by cars.

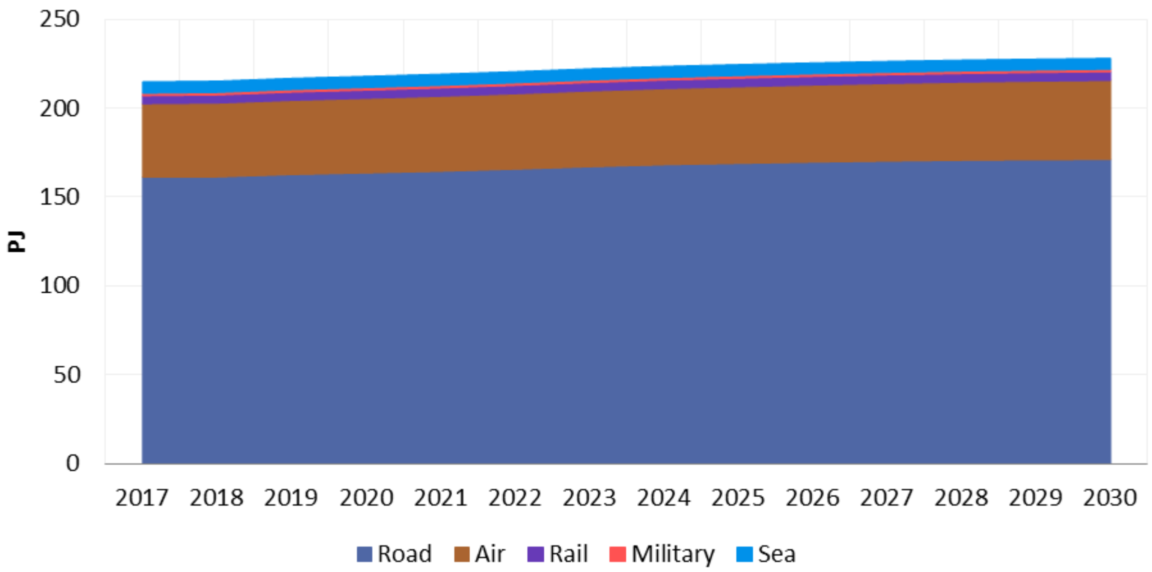
Figure 19 shows energy consumption by use in the period 2017-2030. Road transport will account for 75% of energy consumption, of which cars will account for 47%. Aviation will account for 19%, whereas rail transport, maritime transport and the military will account for the rest.

The increase in energy consumption will mainly come from an increase in energy consumption by road transport. This is expected to increase by 6% in total from 2017 to 2030. Of this, the increase in energy consumption by cars will account for 80%. The reason for this increase in energy consumption is that improvements in energy efficiency will not offset the increase in the number of kilometres driven. It should be stressed that a significant improvement in efficiency is assumed up to 2030.

Energy consumption by the aviation sector is expected to increase by 8% from 2017 to 2030. This increase is due to an increase in air traffic of 35%, while energy efficiency will increase by 26%. The aviation sector has announced ambitious plans for biofuel blending, but these announcements are not assessed to be binding, nor are they assessed to reflect a profitable development pathway for companies in the absence of any new initiatives. Consequently, it is assumed that there will be no biofuel blending in aviation.

The analysis shows that energy consumption in transportation will increase, and this is particularly due to energy consumption by cars. Energy consumption in transportation up to 2030 will continue to be predominantly covered by fossil fuels.

Figure 19: Final energy consumption by the transport sector by use 2017-2030 [PJ].



5.3 Increasing sales of electric cars, but the effect on energy consumption will be limited

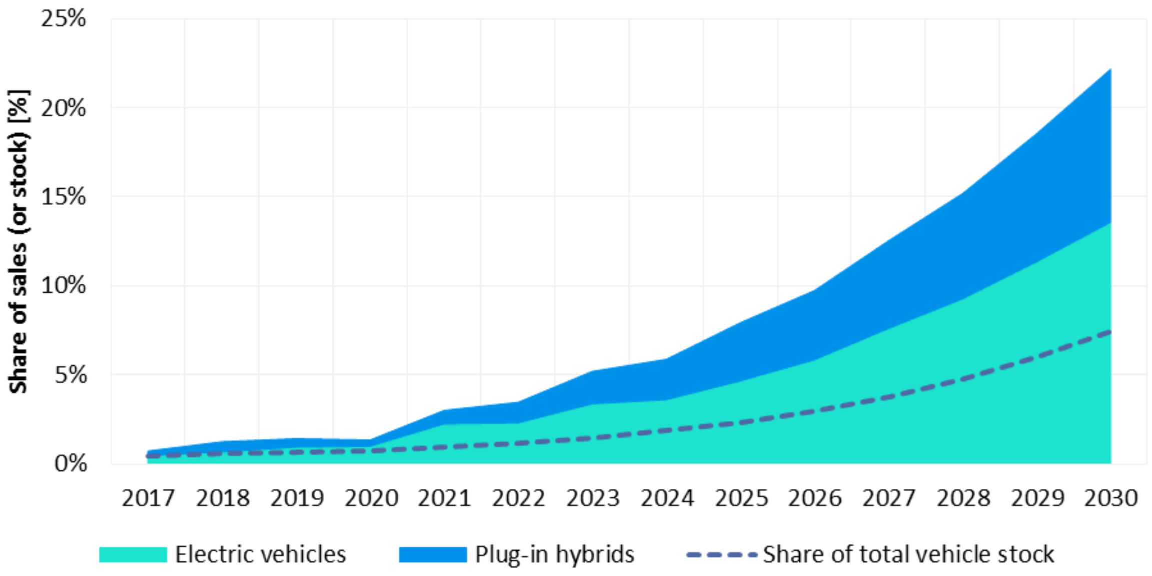
Sales of electrified vehicles (electric cars, plug-in hybrid cars and hydrogen cars) will increase up to 2030 as a result of technological developments and falling technology costs, and are expected to account for 22% of total sales of new cars in 2030 in the absence of any new initiatives. This central estimate means that electrified vehicles will account for 7% of the total number of cars and vans on the road in 2030. The associated electricity consumption is expected to account for 1.2% of total electricity consumption in 2030.

Figure 20 shows the development in electrified vehicles' share of total car sales. It can be seen from the figure that electric cars are expected to account for the largest share of sales of electrified vehicles. Sales of hydrogen cars are expected to be insignificant.

This central estimate for sales of electrified vehicles is subject to significant uncertainty. This has been addressed in sensitivity analyses in Chapter 8.

The analysis shows that electric cars and plug-in hybrid cars as a central estimate are expected to account for 22% of sales and 7% of the total number of cars and vans on the road in 2030. The associated electricity consumption is expected to account for 1.2% of total electricity consumption in 2030. Sensitivity analyses in Chapter 8 examine, among other things, the effect of the significant uncertainty about the trend in sales of electrified vehicles.

Figure 20: Electrified vehicles' share of sales of new cars and the share of cars and vans on the road 2017-2030 [%].



5.4 93% of the energy consumption in transportation will be fossil in 2030

The share of fossil fuels in transportation will fall from 95% to 93% from 2017 to 2030, and this is primarily due to electrification of railways, and to a lesser extent electrification of road transport. An increase in the use of biofuels by busses is expected, which primarily depends on municipal targets.

Consumption of biofuels (excluding biogas) is expected to increase to 10.7 PJ in 2030, corresponding to 5% of energy consumption in transportation. If all gas used in transportation is assumed to be biogas, biogas will contribute 0.4%. [10]

Consumption of electricity is expected to increase to 5.8 PJ in 2030, corresponding to 3% of energy consumption in transportation.

Biofuel blending for road transport will not increase after 2020 in the absence of any new initiatives.

The analysis shows that the share of fossil fuels in energy consumption in transportation will fall from 95% in 2017 to 93% in 2030.

5.5 Significant sensitivities and uncertainties

Transport sector projections are particularly sensitive to assumptions about road traffic[11], the efficiency of vehicles as well as to assumptions about future sales of petrol and diesel cars and electrified vehicles for road transport.

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[10] A significant part of the natural gas expected to be used in transport is expected to be "virtual biogas", i.e. natural gas which, via certificates from biogas producers corresponding to the amount they produce, is sold as biogas. The DECO18 assumes a certain share of biogas blended into natural gas. No assessment has been made as to how much of the natural gas used in transport will be "virtual biogas".

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

The analysis shows that there is methodological uncertainty associated with the calculation of the difference between the standard figure of new cars and their energy consumption in actual use. This uncertainty is represented as an outcome range for greenhouse-gas emissions in order to reflect the significance of the uncertainty. See Chapter 8.4 for more about this and about other significant sensitivities pertaining to transportation.

[11] Number of kilometres driven on roads.

6 Production of electricity and district heating

6.1 Main points

- The renewables share in electricity and district heating consumption will increase to 86% of electricity consumption and 74% of district heating consumption up to 2021. However, in 2030 the renewable energy share of electricity consumption will drop to 57%, due to an increase in electricity consumption in combination with declining renewable energy deployment.

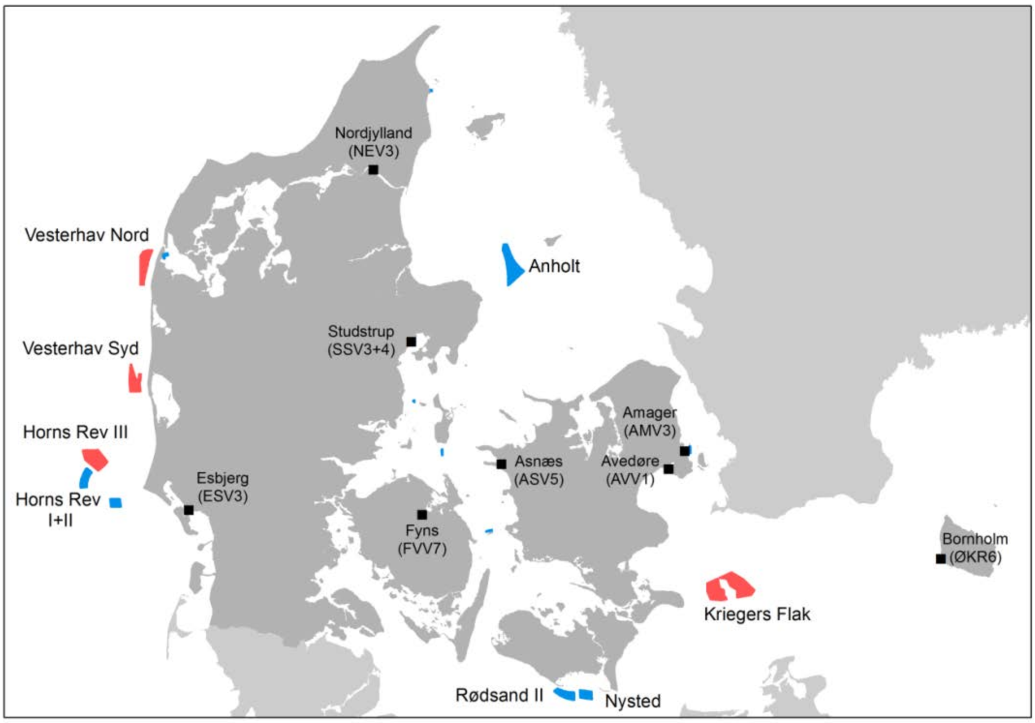
- The share of wind power in electricity consumption will increase to 63% in 2021, but then drop to 39% in 2030 in the absence of any new initiatives. The development from 2022 is due to increasing electricity consumption and to the fact that wind turbines that reach the end of their operational life will not be replaced by new ones in the absence of any new initiatives. The share of solar photovoltaics (PV) in electricity consumption will be constant at around 3%.

- Consumption of solid biomass will increase from 106 PJ in 2017 to 120 PJ in 2021, and will then level off.

- Consumption of coal will fall from 59 PJ in 2017 to 46 PJ in 2020, expected economic profitability of coal-based electricity production from 2023 means that coal consumption will increase again in the absence of any new initiatives.

- District heating production from large heat pumps will increase by 16% per year. This is due to the reduction in the tax on electric heating and phasing out the PSO tariff.

Figure 21: Coal-fired power plants and tendering areas for existing (blue) and approved (red) offshore wind farms.



6.2 The overall picture

Developments in electricity and district heating supply up to 2030 will depend on increasing electricity demand, greater electricity exchange capacity with neighbouring countries and a decline in domestic deployment of electricity production capacity from 2023 in the absence of any new initiatives. Domestic electricity production will increase up to 2023. Denmark is expected to be a net exporter of electricity from 2020 to 2024, but will become a net importer of electricity from 2025 in the absence of any new initiatives. In 2030, net imports of electricity will constitute 19% of electricity consumption (including grid losses), corresponding to 24% of the electricity production.

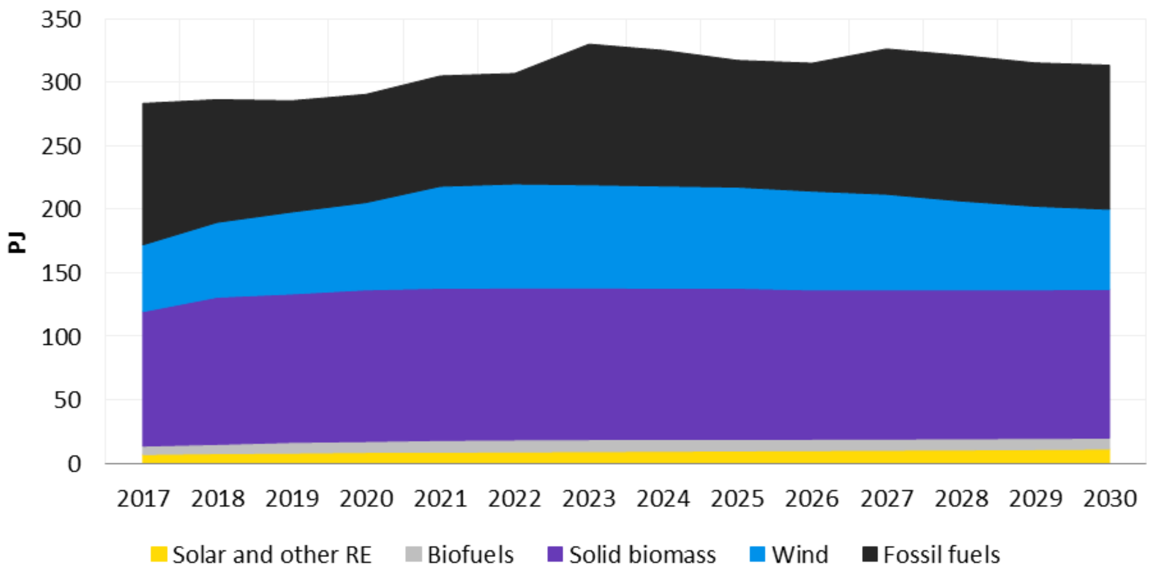
The renewables share in electricity consumption (including grid losses) will increase from 63% in 2017 to 86% in 2021, but will then drop to 57% in 2030. The share of wind power will increase to 63% in 2021, but then drop to 39% in 2030. The share of solar photovoltaics (PV) in electricity consumption will increase from 2% in 2017 to 3% in 2030.

The renewables share in district heating consumption will increase from 62% in 2017 to 74% in 2021, and will then level off. Developments in district heating supply will be characterised by stagnating consumption of district heating up to 2030, and by continued transition from coal and natural gas to biomass up to 2021.

Figure 22 shows that electricity and district heating production is subject to continued transition from coal and natural gas to biomass up to 2020, and on net deployment of 1950 MW onshore wind and offshore wind up to 2022. No further conversions of power plants and no further deployment of wind power are expected from 2023 in the absence of any new initiatives.

The analysis shows that the renewables share of electricity consumption will peak in 2021 and subsequently drop in the absence of any new initiatives. Increasing electricity consumption is expected to be met by an increase in electricity imports, especially after 2023. The renewables share in district heating consumption will peak in 2021 and then level off.

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



6.3 Renewables share of electricity consumption will increase up to 2021

Onshore and offshore wind capacity will see a net expansion of 1950 MW up to 2021/22, of which offshore wind farms account for 1366 MW (Kriegers Flak, Horns Rev 3, Vesterhav Nord/Syd), while onshore wind accounts for 584 MW. A total of 537 MW onshore wind was commissioned in the period 2017-2018 as part of the onshore wind subsidy scheme that ended in February 2018. Furthermore, 189 MW of onshore wind equivalents are included, as the analysis operates with onshore wind equivalents in relation to the 2018/2019 technology-neutral tendering scheme.

No deployment of wind power is expected from 2022 in the absence of any new initiatives.

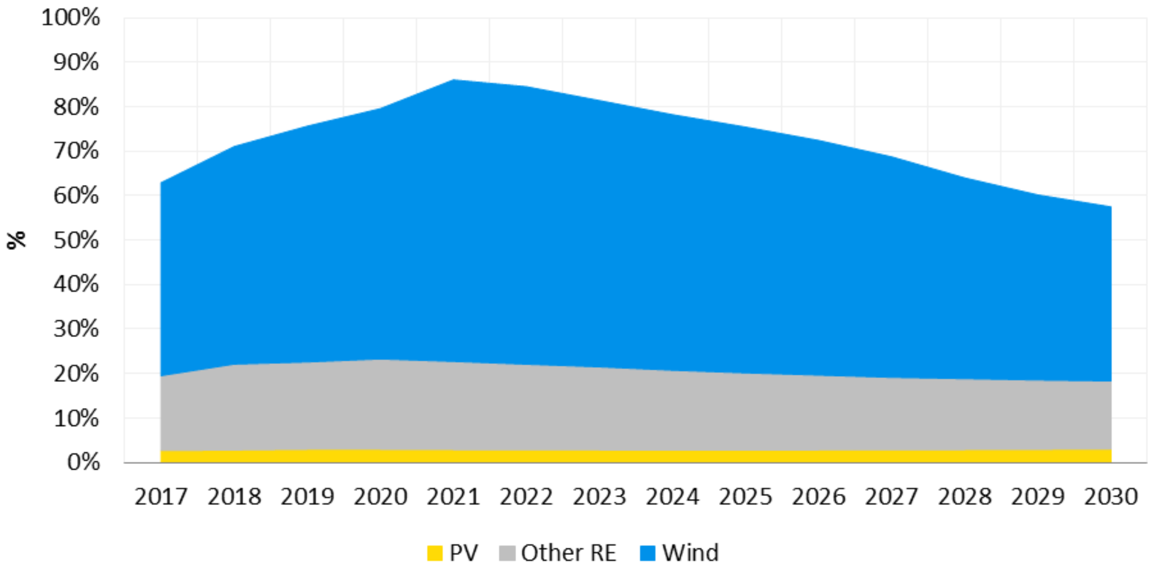
Up to 2030, deployment of an additional 466 MW solar PV is expected, corresponding to a rate of 3.2% per year. The deployment of solar PV depends solely on technological developments and on the profitability associated with the terms set out for so-called 'instant settlement'[12].

Overall, renewables-based, electricity generating capacity will peak in 2021/2022, after which time it will decline in the absence of any new initiatives.

Figure 23 shows that the resulting renewables share in electricity consumption (incl. grid losses) will increase to 86% in 2021, but then drop to 57% in 2030 in the absence of any new initiatives.

The analysis shows that deployment of wind power up to 2021/2022 drives the renewables share in electricity consumption to peak in 2021 at 86%, and then drop in the absence of any new initiatives.

Figure 23: Renewables share in electricity consumption by wind power, PV, and other technologies 2017-2030 [%].



[12] The terms for solar PV were adjusted in 2017 with the transition from hourly-based settlement to instant settlement. Instant settlement of consumption means that electricity tax is paid on electricity supplied by the collective electricity supply grid, and only direct electricity consumption from solar modules' own production is exempt from tax.

6.4 Increasing electricity consumption covered by electricity imports from 2025

Figure 24 shows that electricity consumption, including grid losses, is expected to increase from 33.7 TWh to 44.8 TWh from 2017 to 2030, corresponding to an annual rate of increase of 2.2%.

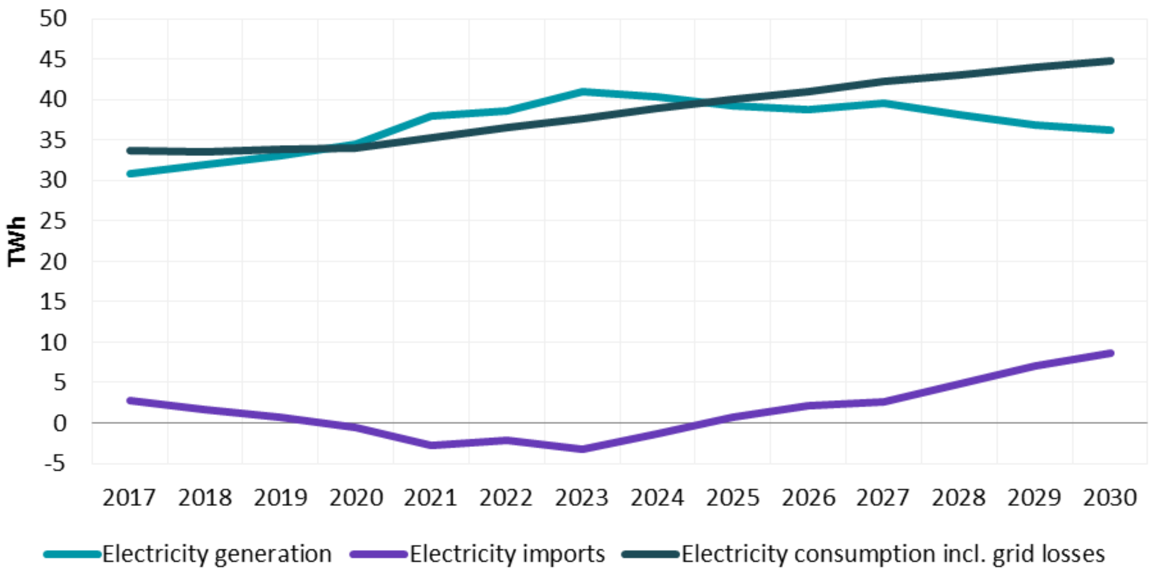
The increasing electricity consumption will be matched by increasing electricity production up to 2023. This depends on deployment of wind power, and on Denmark's possibilities to sell electricity on high-price markets in the Netherlands (via Cobra Cable), the United Kingdom (via Viking Link) and Germany (via the East Coast and West Coast Links). Denmark is expected to be a net exporter of electricity in the period from 2020 to 2024.

Electricity generation will decline from 2024 in the absence of any new initiatives. This depends on no further deployment of wind power following full implementation of the Kriegers Flak offshore wind farm in 2022. From 2025, Denmark is expected to be a net importer of electricity. Net imports are likely to amount to 19% of electricity consumption (including grid losses) in 2030 in the absence of any new initiatives.

All results are based on calculations of normal years with regard to wind power generation and precipitation, for example. Statistical years will be characterised by major fluctuations. Calculation of the electricity trade balance is generally assumed to be associated with considerable uncertainty. The Danish Energy Agency is working to improve the model platform in order to ensure robust modelling.

The analysis shows that the increase in electricity consumption from 2025 is expected to be covered by net electricity imports in the absence of any new initiatives.

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



6.5 More interconnectors reduce differences in electricity prices between countries

Figure 25 illustrates Denmark's interconnectors to neighbouring countries. Denmark has the largest interconnector capacity in Europe relative to domestic electricity consumption, and Denmark has considerable cross-border electricity trade with neighbouring countries. The competitive situation between Denmark and other countries with regard to electricity supply is essential for the scope and direction of cross-border electricity exchange. The projections are based on normal years, and cross-border electricity exchange may therefore deviate in statistical years. A large share of weather-dependent energy sources (hydropower, solar and wind) in Denmark and its neighbouring countries means considerable cross-border electricity exchange between the Nordic countries and the rest of Europe. Furthermore, this makes Denmark a transit country for cross-border electricity exchange between other countries.

Figure 25: Existing interconnectors (green) and interconnectors in 2030 (purple), indicating trading capacities.

Figure 26 shows historical operations, calculated weekly (early 2016 to early 2018) in western Denmark (DK1), and projected expansion of DK1's overall electricity transmission capacity to other market areas up to 2030. Historical operations calculated weekly reveal substantial variations in electricity exchange with Germany and Sweden, in particular. This is due to fluctuations in weather conditions and other market conditions. The figure also shows that electricity transmission capacity to Germany is increasing, and that new capacity is being established to the United Kingdom and the Netherlands.

Figure 27 shows projected trends in average annual electricity spot market prices from 2017 to 2030 for Denmark and selected markets. The Nordic price zone will converge towards a continental western European price zone up to 2020. From 2023, Denmark's electricity prices are likely to move slightly behind prices in Germany, France and the Netherlands, whereas prices in the other Nordic countries will follow each other at a lower, parallel, level. Electricity prices in the United Kingdom start at a higher level and converge towards a continental western European price zone up to 2030.

The analysis shows that interconnectors will reduce differences in electricity prices between market areas. The Nordic price zone will converge towards a common continental western European price zone up to 2020.

Figure 26: Projected expansion of western Denmark's (DK1) electricity transmission capacity up to 2030 to eastern Denmark, Norway, Sweden, the Netherlands, the United Kingdom and Germany, as well as exploitation of existing capacity in the statistical period (early 2016 to early 2018, calculated week-by-week). Expansion data (ENTSO-E, 2016), operating statistics (Energinet.dk, 2018).

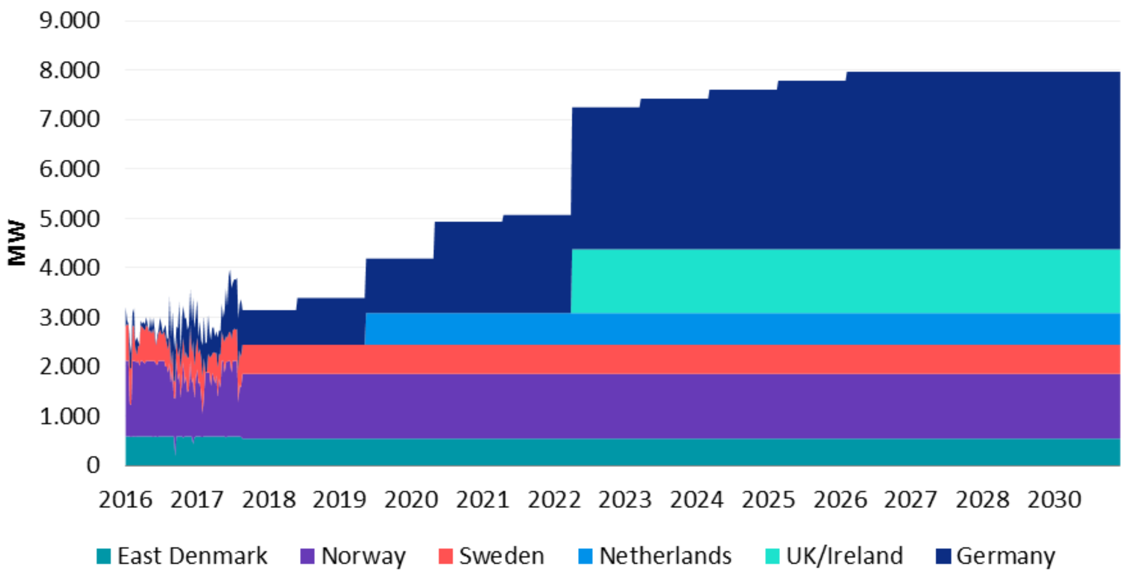
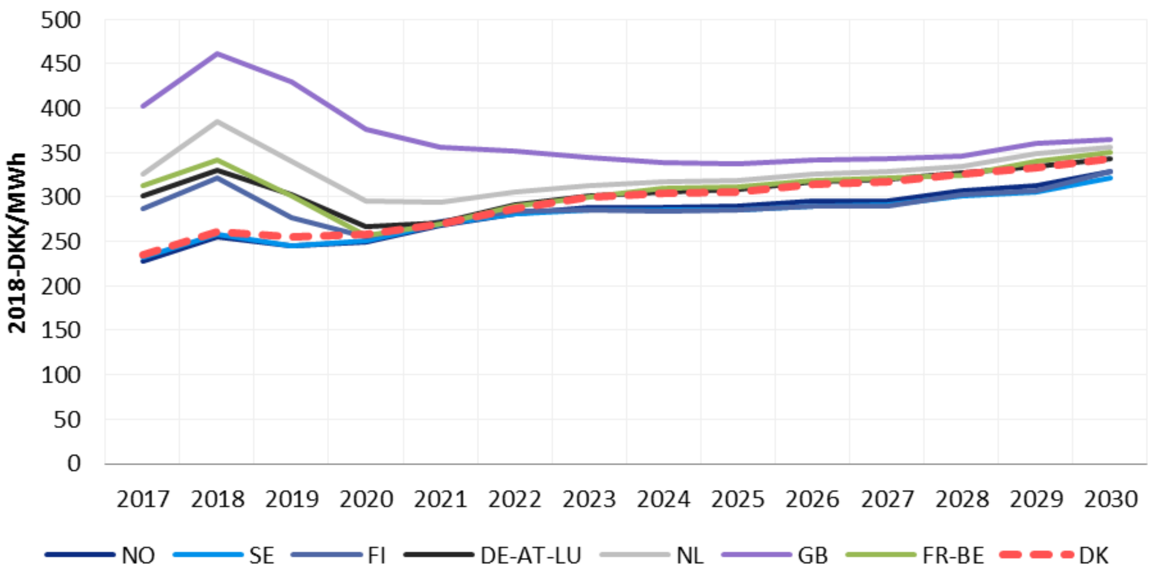


Figure 27: Electricity spot market prices for Denmark and selected price-setting markets 2017-2030 [2018 DKK/MWh]. Prices for all the years are model results. The Danish Energy Agency uses statistical prices and forward prices for 2017-2019 in connection with its utilisation of electricity price results.



6.6 Coal consumption will decline up to 2021, but then increase

Figure 28 shows that the observed (actual) consumption of fossil fuels for electricity and district heating production will decline from 111 PJ in 2017 to 85 PJ in 2020, corresponding to an annual decline of 8.6%.

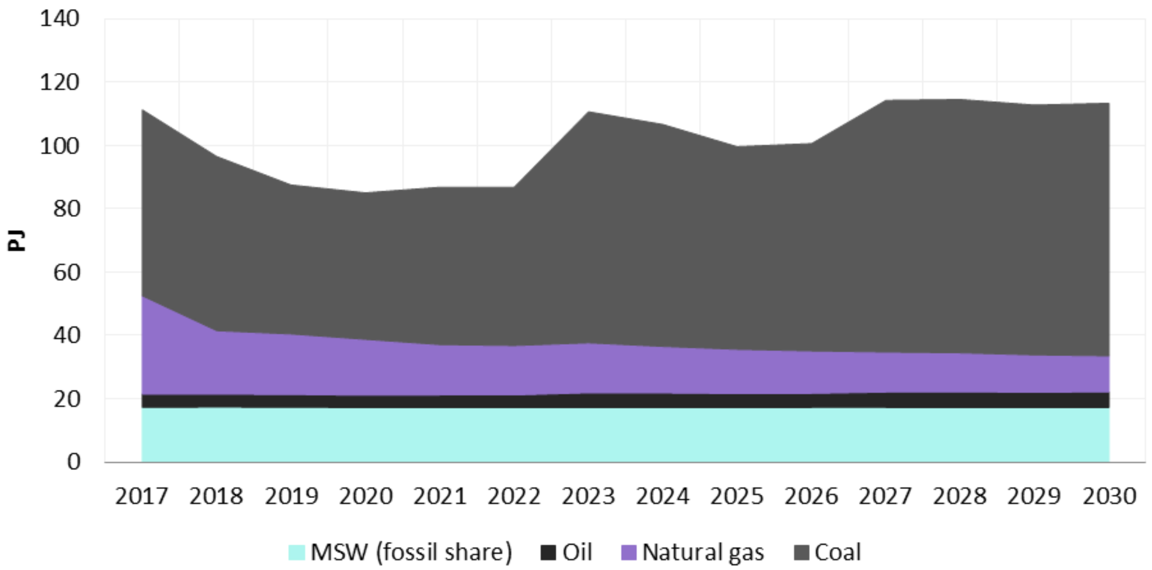
Coal consumption will drop by 7.7% annually up to 2020, subject to an expectation that Ørsted A/S will permanently cease coal-based electricity production at Block 2 at Asnæsværket from 2021, and will temporarily cease coal-based electricity production at Block 4 at Studstrupværket and Block 5 at Asnæsværket in 2019. Moreover, HOFOR A/S is expected to permanently cease coal-based electricity production at Block 3 at Amagerværket from 2020.

The increase in coal consumption from 2023 is due to an expectation that coal-based electricity production will again be economically profitable. This will lead to an increase in consumption of coal at units already in operation, but it is also likely to result in operations at Block 4 at Studstrupværket and Block 5 at Asnæsværket being resumed in 2023 and 2027, respectively, following a financial profitability assessment. This is considered a highly likely development in the absence of any new initiatives. The reason why these units will not be operating in the periods from 2019 to 2022 and from 2019 to 2026, respectively, is that analyses show that, during these years, the plants will not be sufficiently profitable to justify continued operation, let alone reinvestment. Remaining coal-based electricity production units (Block 3 at Studstrupværket, Block 1 at Avedøreværket, Block 3 at Esbjergværket, Block 7 at Fynsværket, Block 6 at Østkraft and Nordjyllandsværket) are likely to continue operations up to 2030.

Consumption of natural gas will decline by 7.4% annually in the period from 2017 to 2030, while oil consumption will remain stable.

The analysis shows that consumption of fossil fuels in electricity and district heating supply will decline up to 2021. Consumption of coal can subsequently be expected to increase in the absence of any new initiatives.

Figure 28: Observed (actual) consumption of fossil fuels in the electricity and district heating sector 2017-2030 [PJ].



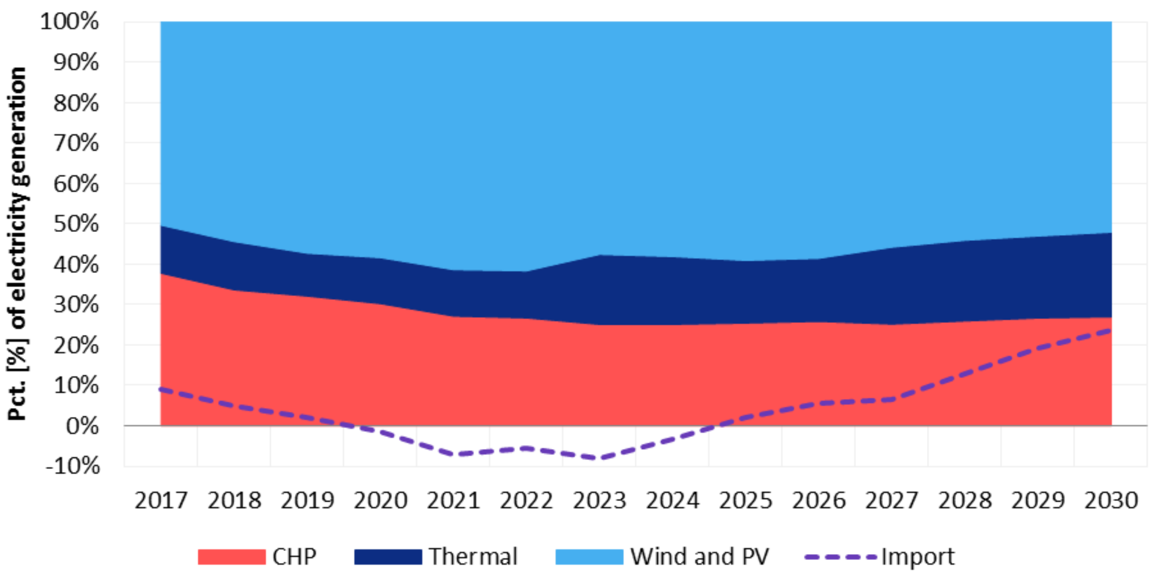
6.7 CHP share will decline then level off

Figure 29 shows that the share of electricity generated in combination with heat will drop steadily from 38% to 25% up to 2023 and then level off. This development is subject to increasing deployment of wind power up to 2022. The share of condensing power will be constant until 2022, after which generation of more condensing power can be expected as a result of coal plants being re-established following a financial profitability assessment.

In 2030, imports of electricity will constitute 24% of domestic electricity production in the absence of any new initiatives.

The analysis shows that the CHP share will follow a downward trend up to 2023, after which it will level off.

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



6.8 The renewables share of district heating will increase and the level off

District heating consumption is expected to be constant throughout the period. Figure 30 shows that consumption of biomass will see an annual increase of just under 5% up to 2020, replacing consumption of coal and natural gas. This development reflects the effect of an expected transition to biomass at several CHP plants. Coal consumption will then stagnate, while consumption of natural gas will see an annual decline of just under 8% throughout the period.

District heating production from heat pumps and electric boilers will increase from 0.8 PJ to 5.3 PJ from 2017 to 2030, corresponding to 16% per year. This is due to a reduction in the tax on electric heating and a phasing out of the PSO tariff. Heat pumps and electric boilers are expected to account for 4% of total district heating production in 2030.

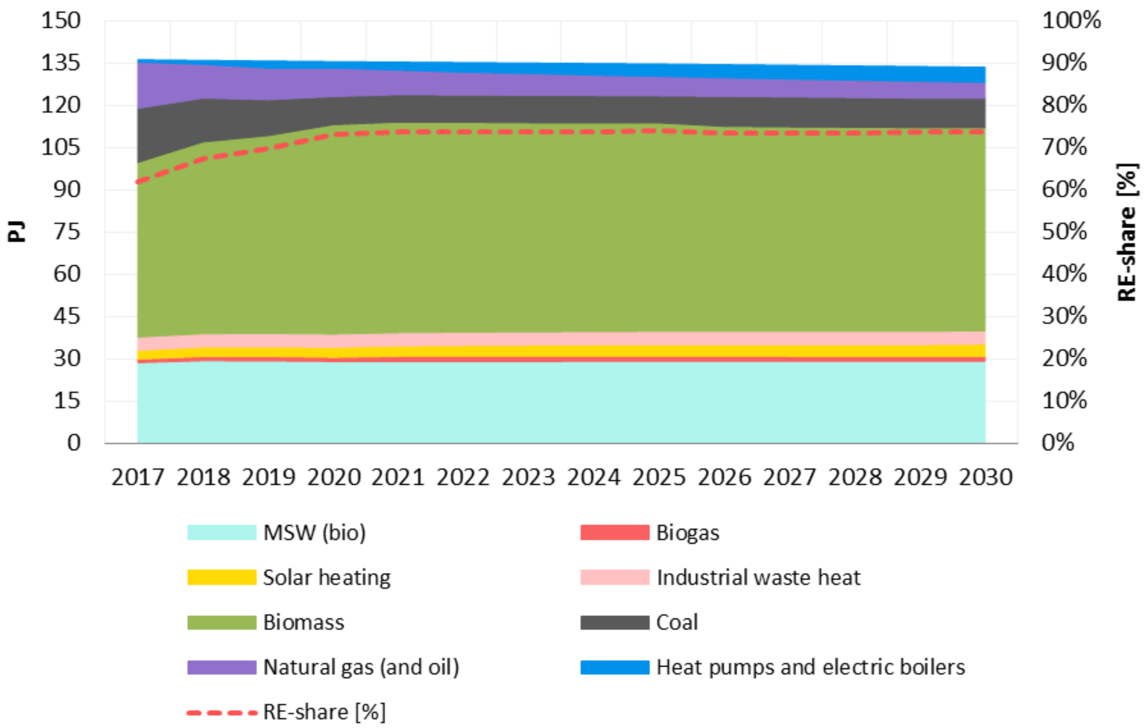
Consumption of solar thermal energy and biogas will increase by 2-3% per year, while consumption of waste heat and surplus heat will be constant throughout the period.

On this basis, the renewables share in district heating is expected to increase from 62% in 2017 to 74% in 2021, and then stagnate.

Non-biodegradable waste is included in fossil fuels, and will account for 10% of district heating production in 2030.

The analysis shows that the renewables share in district heating will increase to 74% up to 2021, and then level off. Heat pumps and electric boilers are expected to account for 4% of total 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. In the figure, the distribution of district heating production is an approximate calculation at plant level, such that district heating from each plant is categorised according to the primary fuel use at the plant. The calculation of the renewables share is based on an accurate statement of renewable energy consumption.



6.9 Significant sensitivities and uncertainties

Projections of electricity and district heating supply are particularly sensitive to developments in electricity consumption, prices of fuels and CO_2 allowances, deployment of wind power and solar PV, and specific decisions concerning coal-fired power plants, for example.

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

7 Emissions of greenhouse gases

7.1 Main points

- Up to 2021, Danish greenhouse gas emissions are likely to decline to a level of 39% below the baseline year 1990. Subsequently, emissions are expected to increase in the absence of any new initiatives. This development particularly depends on energy-related emissions; there will be no major changes in the other sectors.

- Denmark will meet and exceed its share of the EU goal for non-ETS sectors for the period 2013-2020.

- Non-ETS emissions for the period 2021-2030 are expected to fall short of the EU obligation by between 32 to 37 million tonnes CO2-eq., subject to an uncertainty of +/- 10 million tonnes CO2-eq.

7.2 The overall picture

Since 1990 - the UN baseline year for calculation of climate efforts - total emissions have declined by 17 million tonnes per year from 70.8 million tonnes to 53.5 million tonnes in 2016, which corresponds to a reduction of 24% (IPCC, 2017).

Energy-related emissions, which cover emissions from electricity and heat production and from energy consumption in industry, services, and households, have historically been responsible for the largest percentage of emissions. However, energy-related emissions have been reduced by 22 million tonnes relative to 1990, corresponding to 45%. In comparison, emissions from agriculture fell by 17%, and environmental emissions[13] fell by 18%, while emissions from the transport sector increased by 13%.

Up to 2021, energy-related emissions are likely to see a further decline relative to 1990 of 21 percentage points to 67% relative to 1990. In the absence of any new initiatives, increasing electricity consumption and a decline in deployment of renewable energy will give rise to an increase in consumption of coal, oil and natural gas after 2021. The background for this trend is described in Chapter 6. The consequence will be that energy-related emissions after 2021 will increase towards 2030. In the absence of any new initiatives, in 2030, energy-related emissions are likely to have been reduced by 49%, emissions from agriculture are likely to have declined by 14%, and environmental emissions are likely to have declined by 30%, while emissions from the transport sector are expected to have increased by 9-16%. These trends are all relative to 1990. The outcome range for emissions from the transport sector is due to methodological uncertainty about the actual energy efficiency of new cars, see Chapter 8.4.

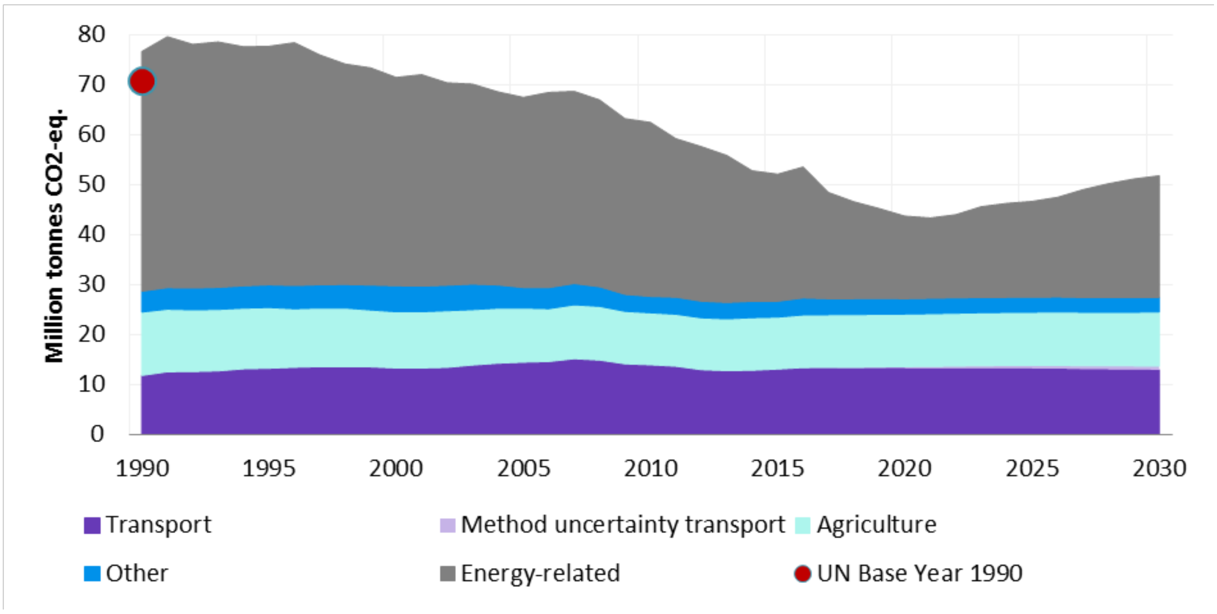
On this basis, in 2020 total emissions are expected to have been reduced by 38-39% relative to the baseline year 1990, and to subsequently reach an all-time low of 43 million tonnes in 2021, corresponding to a reduction of 39% relative to the baseline year 1990. In the absence of any new

[13] Environmental emissions include industrial gases and emissions from managing waste, wastewater and similar.

initiatives, total emissions are expected to subsequently increase up to 2030 to 51-52 million tonnes, corresponding to a reduction of 27-28% relative to the baseline year 1990.

The analysis shows that Denmark's emissions of greenhouse gases have been declining since 1990. This development is expected to continue up to 2021, after which emissions will increase up to 2030 in the absence of any new initiatives.

Figure 31: Emissions of greenhouse gases from 1990-2030 and in the 1990 UN baseline year [mill. tonnes CO2-eq.]. Figures have been adjusted for outdoor temperature relative to normal years (climate-adjusted) and electricity trade with other countries. The reduction has been measured relative to the 1990 UN baseline year, which is based on observed (actual) emissions and determined as part of the UNFCCC.



7.3 Observed or adjusted emissions?

Denmark's emissions of greenhouse gases are calculated according to international standards[14] stemming from the UNFCCC. Consequently, reduction efforts are measured relative to observed emissions in the 1990 baseline year. An internationally recognised common base year serves as the foundation for comparing reduction efforts by individual countries.

Figure 32 shows observed and adjusted emissions from 1990-2030. Adjusted emissions have been adjusted for fluctuations in outdoor temperatures compared to a normal year (climate-adjusted) and for fluctuations in electricity trade with other countries.[15] Historically, Denmark has

[14] All anthropogenic emissions are calculated, but only emissions from Danish territory are included in the Danish greenhouse gas inventories. Emissions from international maritime traffic and air traffic are not included in Danish statistics. Consumption of biomass in the energy sector (burning of wood chips and wood pellets, for example) is calculated as greenhouse-gas neutral.

[15] The net exchange of electricity has been adjusted based on a technical-economic assessment according to which, in marginal terms, electricity is generated by (in the case of imports) or replaces (in the case of exports) an average of thermal electricity production in Denmark, i.e. a combination of coal, natural gas, oil and solid biomass.

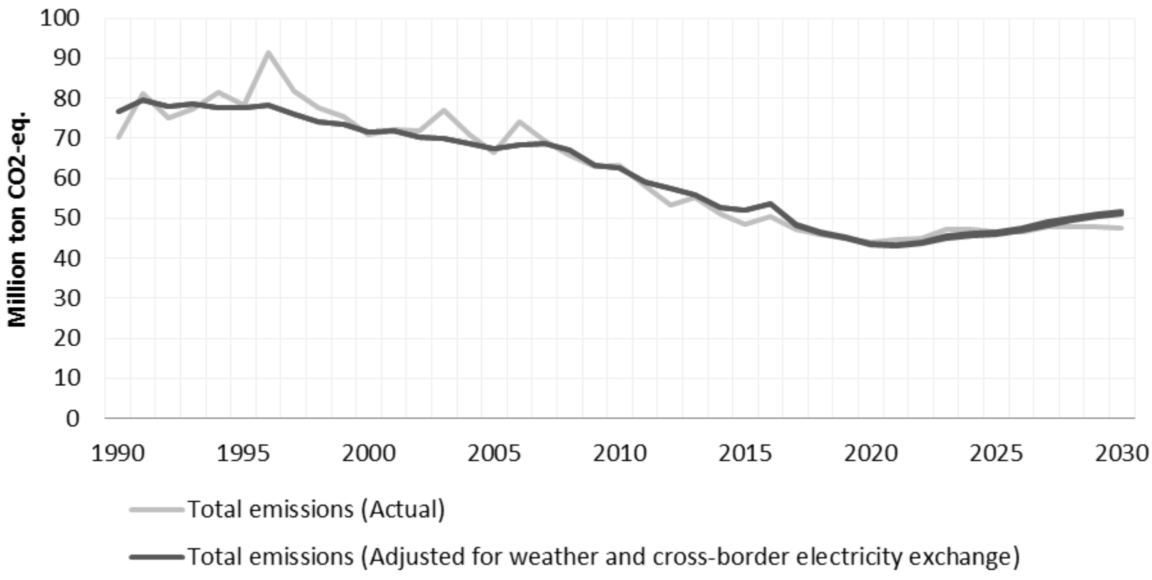
been a net importer of electricity in some years, while in other years, it has been a net exporter, but over time, adjusted emissions have largely corresponded to the observed emissions.

Figure 32 shows that observed emissions reach a stable level from 2023, while adjusted emissions increase. This divergence is due to the circumstance that, in the absence of any new initiatives, net imports of electricity are expected to increase systematically, as described in Chapter 6, which, in turn, is due to a combination of increasing electricity consumption and declining domestic deployment of new electricity generation capacity.

Adjustments have been made to ensure that the emissions reflect the actual interrelated system impacts of developments in Danish energy consumption. The systematic deviation between observed and adjusted emissions from 2023 means that the climate footprint of Danish electricity consumption in the period 2023-2030 will be higher than what will be reflected in the observed emissions.

The analysis shows that increasing net imports of electricity will lead to a systematic deviation between observed and adjusted emissions. The systematic deviation between observed and adjusted emissions from 2023 means that the climate footprint of Danish electricity consumption in the period 2023-2030 will be higher than what will be reflected in the observed emissions.

Figure 32: Observed (actual) and adjusted total emissions 1990-2030 [mill. tonnes CO2-eq.].



7.4 Over-achievement of non-ETS reduction targets 2013-2020

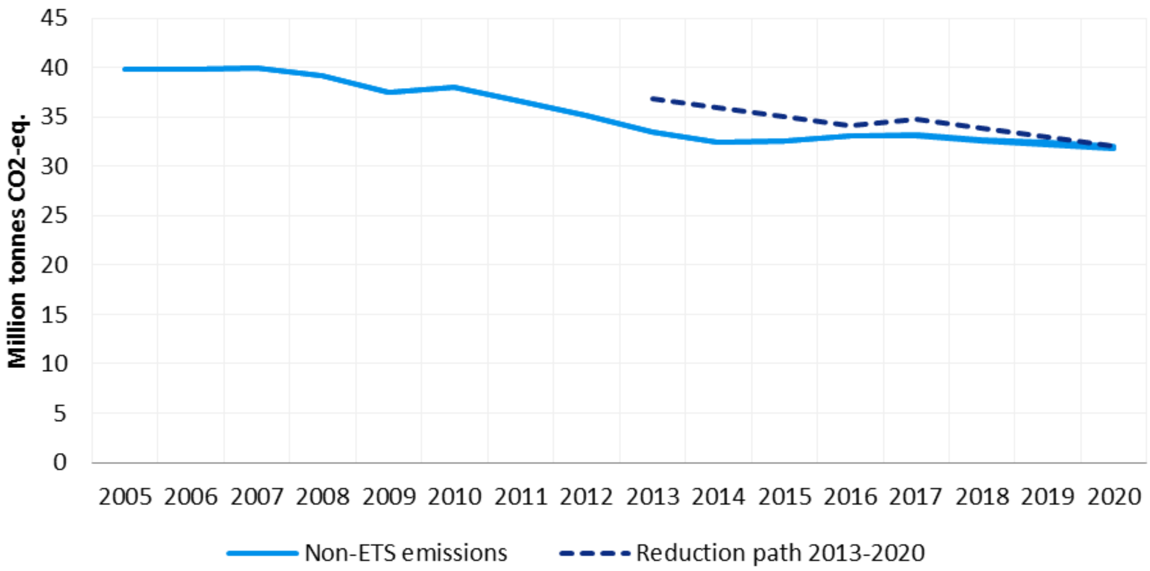
Under the 2009 EU climate and energy package, Denmark is committed to reducing emissions from non-ETS sectors by 20% by 2020 relative to the 2005 level. This includes reaching gradually tighter annual sub targets. Overachievement in one year can be used to meet targets for subsequent years up to 2020.

Figure 33 shows that Denmark will overachieve the EU target for non-ETS sectors for the period 2013-2020.

In 2017, the annual sub targets for 2017-2020 were adjusted upwards. Consequently, Denmark is expected to overachieve in all years in the commitment period. Total accumulated overachievement will amount to 14 million tonnes CO2-eq. for the period. The overachievement cannot be carried forward to the next commitment period, 2021-2030.

The analysis shows that Denmark will meet and exceed its EU obligation for non-ETS sectors for the period 2013-2020.

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



7.5 Achievement of non-ETS reduction targets 2021-2030 will fall short by 32-37 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. This includes reaching gradually tighter annual sub targets. Up to 2020, minor adjustments to the overall reduction targets may potentially occur.

The projection shows that in all years, emissions are likely to exceed the annual sub targets, and that the total accumulated shortfall will be 32-37 million tonnes CO2-eq. in 2030.

The range for the total shortfall is due to uncertainty about the actual energy efficiency of new cars, see Chapter 8.4.

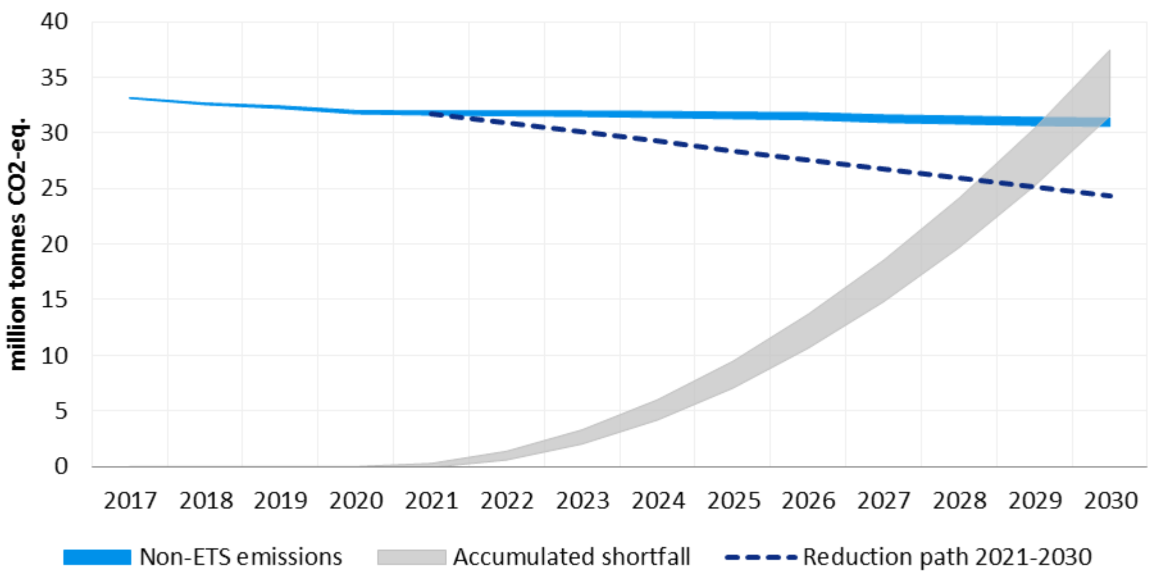
Figure 34 shows that, in 2030, emissions are expected to fall to a range around 31 million tonnes CO2-eq., corresponding to a reduction of 21%-23% compared to 2005.

The expected reduction need for the period 2021-2030 is generally sensitive to even relatively minor variations in projected emissions. Between DECO17 and DECO18, expectations for non-ETS emissions for the period 2021-2030 have been adjusted upwards by 4-10 million tonnes, corresponding to 1%-3%. As a result, the central estimate for the projected shortfall for the period has been increased from 28 million tonnes to 32-37 million tonnes CO2-eq.[16]

Apart from the outcome range associated with uncertainties concerning cars' actual energy efficiency, trends in transport demand and deployment of electric cars as well as trends in livestock constitute significant sensitivities. This means that emissions may exceed or be less than the central estimate. On the basis of the partial sensitivity calculations in Chapter 8, it is assessed that emissions may vary by around +/- 10 million tonnes CO2-eq.[17] Based on this uncertainty, the shortfall could be as low as 22-27 million tonnes and as high as 42-47 million tonnes.

The analysis shows that non-ETS emissions are expected to exceed the annual sub targets in all years. The accumulated shortfall is calculated at 32 to 37 million tonnes CO2-eq., subject to an uncertainty of +/- 10 million tonnes CO2-eq.

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



7.6 Uncertainty concerning contributions from LULUCF to the 2021-2030 reduction targets

Under the EU 2030 climate and energy policy framework, it will be possible to include a so-called LULUCF contribution in 2021-2030 reduction efforts. LULUCF is an acronym for Land Use, Land-

[16] As a consequence of the results of the DECO18, the reduction trajectory for the period 2021-2030 has also been adjusted slightly towards a more relaxed target.

[17] The sensitivity interval is described on the basis of sensitivity analyses of transport, agriculture and fuel prices in Chapter 8.

Use Change and Forestry, and covers carbon uptake and emissions in connection with land use and forestry in Denmark.

Denmark can include contributions up to 14.6 million tonnes CO_2-eq. from LULUCF to support reduction efforts for non-ETS sectors in the period 2021-2030. Calculations and projections of LULUCF are associated with considerable uncertainty.

Projections of LULUCF and the calculation of LULUCF contributions to the 2021-2030 commitment will be carried out by the Danish Centre for Environment and Energy at Aarhus University (DCE) and will not be completed until after the publication of DECO18.

The analysis shows that Denmark has the option of including a reduction contribution of up to 14.6 million tonnes CO_2-eq. from LULUCF. Calculation of the contribution will be completed after publication of the DECO18.

7.7 Significant sensitivities and uncertainties

Projections of greenhouse gas emissions are particularly sensitive to the energy efficiency of vehicles, CO_2 allowance prices, technological developments, transport volume and changes in agricultural production.

With regard to the energy efficiency of vehicles, this sensitivity means that the calculation of greenhouse gas emissions operates with an outcome range. The background for this is described in Chapter 8.4.

With regard to CO_2 allowance prices and technological developments, the assumptions have an impact on the technological solutions selected. A high CO_2 allowance price or a low cost of renewable energy technology will render the use of fossil fuels in the energy sector relatively more expensive, contribute to implementation of renewable energy, and thereby lead to a fall in emissions. Sensitivity effects will primarily be in the ETS sector, but may also to some extent occur outside the ETS sector.

With regard to transport demand, the assumptions have a significant impact on effects outside the ETS sector. This sensitivity is described in Chapter 8.

With regard to agricultural milk production and the amount of livestock, milk quotas, environmental legislation in other EU countries and production and demand outside the EU are significant factors. This sensitivity is described in Chapter 8.

Finally, it must be highlighted that biomass-based energy consumption is carbon-neutral in national greenhouse gas inventories, in line with international guidelines prepared by the UN climate panel (IPCC). Felling of trees counts as a CO_2 loss in the land management part of the inventory. When biomass is incinerated and recovered for energy, the carbon effect has already been accounted for in the overall inventory. Biomass is also greenhouse-gas neutral in the sense that, over time, the released CO_2 will be absorbed by trees again. Consequently, there may be a basis for sustainable use of biomass for energy production. However, this assumes that biomass is produced in a sustainable manner without permanent loss of carbon in plants and soil, and that it is replaced by new biomass, i.e. replanting and sustainable management of forests designated for production.

Danish electricity and district heating producers are covered by a voluntary sector agreement on securing sustainable biomass. Physically, burning biomass will be associated with CO_2 emissions. These are calculated by Statistics Denmark (Statistics Denmark, 2018b). This subject is described in further detail in the Danish Energy Agency bioenergy analysis (Danish Energy Agency, 2014).

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

8 Significant sensitivities and partial sensitivity analyses

8.1 Main points

- There are a number of central assumptions for which partial sensitivity analyses have been conducted, for example the electricity consumption of data centres, the trend in fossil fuel prices, transport demand and choice of vehicles in sales of new cars.
- The sensitivity analyses show that central assumptions have a significant impact on key results in the projections. For example, it is assessed that non-ETS emissions may vary by around +/- 10 million tonnes CO2-eq. in the period 2021-2030.
- Methodological uncertainty about the observed (actual) energy consumption of vehicles has resulted in an outcome range for greenhouse gas emissions reflecting this uncertainty.

8.2 Selection of sensitivities

A number of assumptions have been identified and selected for 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.

Table 1: Selected sensitivities and parameter variations. Assumptions underpinning the Danish Energy Agency's central estimates are described in the DECO18 memorandum on assumptions (Danish Energy Agency, 2018b). Dairy cattle, central estimate based on (Jensen, 2017).

	Sensitivity	DECO18 Central Scenario	Parameter variation 2030
A	Electricity consumption of data centres	'Linear growth' scenario	'Exponential growth' and 'Denmark deselected' scenarios, i.e. scenarios with the highest and lowest electricity consumption.
B	CO2 allowance price	Central estimate by the Ministry of Finance	The IEA's projection of the CO2 allowance price from the New Policies Scenario, corresponding to the EU targets.
C	Fossil fuel prices	Ministry of Finance/DEA/IEA central estimate	+/- 30% for coal; +/- 40% for natural gas; and +/- 50% for crude oil, corresponding to a variation within a standard deviation of historical fluctuations.
D	Deployment of solar PV	DEA central estimate	+ 100% new capacity
E	Electrified vehicles	DEA central estimate	+ 100% share of sales of new cars
F	Less improvement in energy efficiency, industry and services	DEA central estimate	Smaller effect of energy saving efforts by energy companies, final energy consumption of the sector will increase by 14 PJ by 2020
G	Dairy cattle	DEA central estimate	+/- 100,000 livestock
H	Transport volume	DEA central estimate	-20% transport volume
I	Decommissioning of coal-fired electricity generation capacity, with missing heat production being partly replaced by heat pumps	DEA central estimate	ASV5/SSV4 remain shut down, AVV1 cessation of coal from 2023, ESV3 to be shut down in 2022 +75 MJ/s VP, FYV7 to be shut down in 2025 +75 MJ/s VP, SSV3 cessation of coal after 2022, NEV3 to be shut down in 2029 +75 MJ/s VP

8.3 Result of partial sensitivity analyses

Table 2 summarises the results of the partial sensitivity analyses. For each sensitivity, the change is indicated relative to the central result (delta value). The upper table shows changes in 2020, while the lower table shows changes in 2030. The following sections focus on changes in 2030.

Uncertainty about electricity consumption for data centres affects the renewables share in 2030 from -0.6 to +1.2 percentage points, while electricity imports are affected from +2.7 to -5.5 TWh. In both cases, the effects are for higher and lower electricity consumption, respectively.

Uncertainty about the CO2 allowance price and fossil fuel prices affects the renewables share in 2030 from +0.6 to -1.5 percentage points, while the electricity price sees an effect of +/- 80 DKK/MWh (DKK 0.08/kWh), and the non-ETS shortfall (non-ETS emissions 2021-2030) sees an effect from -1.9 to 4.3 million tonnes CO2-eq. In all cases, the effects are for a higher and lower price level, respectively.

Uncertainty about the number of dairy cows (+/- 100,000 units) affects the non-ETS shortfall by +/- 4.3 million tonnes CO2-eq.

Uncertainty about transport demand has an effect on the renewables share of +0.4 percentage points in 2030 in case of less demand, while the non-ETS shortfall is affected by -3.8 million tonnes CO2-eq.

Uncertainty about decommissioning of coal-fired electricity generation capacity will affect electricity imports by +8.7 TWh in 2030 in case of accelerated decommissioning, while total greenhouse gas emissions (ETS and non-ETS) will be affected by -10.7 million tonnes CO2-eq.

Uncertainties about deployment of photovoltaic solar modules and sales of electrified vehicles will affect the renewables share by +0.2 percentage points in 2030 in case of increased deployment/sales. Increased sales of electrified vehicles will affect the non-ETS shortfall by -1.49 million tonnes CO2-eq.

The probability of the individual sensitivities' variation has not been assessed, nor has an overall risk analysis been performed. The sensitivity analyses indicate that central assumptions have a significant impact on the key results in the projections.

Although the resulting sensitivity effects cannot be readily aggregated, the partial results for transport, agriculture and fuel prices are assessed to make up a sufficient basis for indicating that non-ETS emissions in the period 2021-2030 may vary by around +/- 10 million tonnes CO2-eq., corresponding to approx. 3% of total non-ETS emissions for the period.

The analysis shows that there are a number of central assumptions for which partial sensitivity analyses have been conducted. The sensitivity analyses show that central assumptions have a significant impact on key results in the projections. For example, it is assessed that non-ETS emissions may vary by around +/- 10 million tonnes CO2-eq. in the period 2021-2030.

Table 2: Sensitivity results for 2020 and 2030 calculated as delta values (differences) relative to the central assumption scenario. Values are specified for the relevant year (2020 or 2030), except for the result 'Non-ETS 2021-2030', which reflects accumulated non-ETS emissions 2021-2030.

	Sensitivity results 2020.	Renewables share (RES)	Fossil consumption	Electricity price	Electricity imports	Non-ETS 2020	ETS + Non-ETS
ID	**Description**	**Percentage**	**PJ**	**DKK/MWh**	**TWh**	**Mill. tonnes CO2-eq.**	
-	**DECO18 Central Scenario**	**41.95**	**433.0**	**254.2**	**-0.5**	**32.0**	**43.7**
A+	Data centres 'Exponential growth'	-0.11	0.3	0.6	0.4	-	0.2
A-	Data centres 'Denmark deselected'	-	-	-	-	-	-
B	Higher CO2 allowance price	-0.02	1.1	36.0	-0.4	0.1	-0.1
C+	High fossil prices	0.27	-4.4	50.0	0.3	-0.1	-0.2
C-	Low fossil prices	-0.36	19.9	-52.3	-2.2	0.2	0.6
D	Increased deployment of	0.05	-0.1	-0.1	-0.1	-	-
E	Increased sales of electric vehicles	0.09	-0.7	-	-	-	-
F	Less improvement in energy	-0.34	8.4	1.3	0.9	0.3	0.9
G	More(+)/fewer(-) dairy cows	-	-	-	-	+/- 0.4	+/- 0.4
H	Reduced transport demand	0.21	-2.8	-	-	-0.2	-0.2
I	Decommissioning of coal-fired	-	-	-	-	-	-

	Sensitivity results 2030	Renewables share (RES)	Fossil consumption	Electricity price	Electricity imports	Non-ETS 2030	Non-ETS 2021-2030 acc.	ETS + Non-ETS
ID	**Description**	**Percentage**	**PJ**	**DKK/MWh**	**TWh**	**Mill. tonnes CO2-eq.**		
-	**DECO18 Central Scenario**	**39.81**	**470.2**	**339.5**	**8.6**	**31.4**	**-**	**51.8**
A+	Data centres 'Exponential growth'	-0.56	1.1	1.5	2.7	-	-	1.5
A-	Data centres 'Denmark deselected'	1.18	-1.9	-2.8	-5.5	-	-	-3.0
B	Higher CO2 allowance price	0.04	-17.9	83.3	1.2	0.3	1.75	-2.1
C+	High fossil prices	0.60	-7.8	79.6	-0.2	-0.2	-1.92	-0.7
C-	Low fossil prices	-1.51	44.1	-80.3	-3.9	0.7	4.26	1.9
D	Increased deployment of photovoltaic	0.23	-0.3	-0.5	-0.4	-	-	-0.2
E	Increased sales of electric vehicles	0.24	-3.0	0.5	0.4	-0.4	-1.49	-0.1
F	Less improvement in energy	-	-	-	-	-	-	-
G	More(+)/fewer(-) dairy cows	-	-	-	-	0.5	+/- 4.26	+/- 0.5
H	Reduced transport demand	0.43	-7.5	-	-	-0.5	-3.71	-0.5
I	Decommissioning of coal-fired	0.11	-76.3	9.7	8.7	0.1	0.51	-10.7

8.4 Significant sensitivities and uncertainties for the transport sector

Transport sector projections are particularly sensitive to assumptions about road traffic, the efficiency of vehicles as well as to assumptions about future sales of petrol and diesel cars and electrified vehicles for road transport.

The trend in road traffic is estimated to be +/- 20% of the assumed figure. This uncertainty results in an outcome range for total energy consumption in the transport sector around 16 PJ (+/- 8 PJ), corresponding to 7% of total energy consumption in the transport sector. However, this uncertainty only affects fossil fuels' share of energy consumption in the transport sector to a lesser degree (< 0.5%).

With regard to the energy efficiency of vehicles, DECO18 is based on an assessment of the actual (observed) energy efficiency of vehicles when in operation. Energy efficiencies are calculated on the basis of the European Environment Agency's COPERT 5 emissions model (Emisia, 2018; European Environment Agency, 2016), which adjusts for the difference between standard figures of new cars and their energy consumption in actual use (observed energy consumption).

The European Environment Agency's method is based on newly registered vehicles from 2009-2011. However, the International Council on Clean Transportation (ICCT) has presented measurements demonstrating that after 2011, newly registered vehicles have exhibited gradually larger differences between standard figures and observed energy consumption (ICCT, 2016, 2017). For more elaborate information, see the annex on transport projections in the memorandum on assumptions (Danish Energy Agency, 2018b).

Against this background, the European Environment Agency's method is being revised and there is currently uncertainty with regard to any future adjustment of standard figures. Assumptions about the observed (actual) energy efficiency of vehicles are particularly important for the calculation of non-ETS emissions. This uncertainty has resulted in an outcome range for greenhouse gas emissions that reflects the significance of the uncertainty linked to use of the European Environment Agency's existing adjustment and the measurements presented by the ICCT, respectively.

Future sales of petrol and diesel cars are assumed to follow the statistical breakdown of sales in 2016. However, new knowledge suggesting that many diesel vehicles in practice exceed the limit values for emissions of local air pollutants has led to several European cities considering imposing a ban on diesel vehicles. This could cause a fall in sales of diesel vehicles. If diesel vehicles are replaced by petrol vehicles, energy consumption in the transport sector will increase, because petrol vehicles are less energy-efficient than diesel vehicles. The results are therefore highly sensitive to this uncertainty.

With regard to electrified vehicles, sales trends are associated with significant uncertainties. This is due to the uncertainty linked to assumptions about price developments for batteries and other components that determine the manufacturing costs for electrified vehicles. Moreover, there is uncertainty about the preferences of consumers and businesses with regard to ownership and use.

Table 3 shows the consequence of different estimates of electrified vehicles' share of total sales of new vehicles for overall consumption of fossil fuels in 2030 and for non-ETS emissions for the period 2021-2030. The alternative estimates are not based on specific variations in underlying assumptions.

Table 3: Sensitivity analysis for the share of electrified cars and vans in total sales of new vehicles [%] and the resulting change in the share of the total population of cars and vans, as well as the change in total observed consumption of fossil fuels in 2030 [% (PJ)] and the change in non-ETS emissions for the period 2021-2030 [mill. tonnes CO2-eq.]. The alternative estimates of electrified vehicles' share of total sales of new cars are not based on specific variations in underlying assumptions.

Share in total sales of new vehicles, central estimate [%]	Share in total sales of new vehicles in 2030 [%]	Share of total population in 2030 [%]	Consumption of fossil fuels in 2030, central estimate [PJ]	Non-ETS emissions 2021-2030, central estimate [mill. tonnes CO2-eq.]
-50%	11%	4%	2.7 PJ	+0.7
Central estimate	22%	7%	-	-
+100%	44%	14%	-5.4 PJ	-1.7
+200%	66%	20%	-10.9 PJ	-3.1

The analysis shows that central assumptions about transport demand and choice of vehicle have a significant impact on key results in the projections. Note also that methodological uncertainty about the observed (actual) energy consumption of vehicles has resulted in an outcome range for greenhouse gas emissions reflecting the significance of the uncertainty.

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