Danish Energy Agency

2020

Denmark's Climate and Energy Outlook

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

Denmark's Climate and Energy Outlook 2020
(In Danish: Basisfremskrivning 2020 – Danmarks Klima- og Energifremskrivning)
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1 Welcome to Denmark's Climate and Energy Outlook 2020

Denmark's Climate and Energy Outlook (DCEO20) is a technical assessment of how Danish greenhouse gas emissions, and Danish energy consumption and energy production, is expected to evolve over the period up to 2030 based on the assumption of a frozen-policy scenario. A frozen-policy scenario describes a scenario with existing measures, i.e. in which no new policies are introduced.

DCEO20 is therefore the Danish Energy Agency's best guess at what the future will be like with regard to climate and energy-related aspects if no new measures are decided in the climate and energy area other than those adopted by the Danish Parliament as of 1 May 2020, or those that the Parliament at the time is expected to adopt as a consequence of binding agreements. This means that the impacts of the climate action plan for a green waste sector adopted on 16 June 2020 (The Danish Government et al, 2020a) as well as the agreement of 22 June on climate measures in industry and energy sectors (The Danish Government et al, 2020b) have not been included in DCEO20.

The methodology behind the projections in DCEO20 is well-defined and is based primarily on technological costs and on the rational options and financial viability requirements of players in given markets. Large, existing projects are also included if there is an approved application or a funding commitment, for example for the conversion of a power plant from coal to biomass. The assumed 'policy freeze' pertains to climate and energy policy only and does not imply that development in general will come to a halt. For example, economic growth and demographic trends are not part of the freeze. Figure 1 illustrates the temporal scope of the most important political measures included in DCEO20.

DCEO20 thus serves to examine to what extent Denmark will meet it's climate and energy targets and commitments within the framework of current regulation. Denmark's Climate and Energy Outlook can be used as a technical reference when planning new measures in the climate and energy area, and when assessing the impact of such measures.

1.1 DCEO20 Focuses on Emissions of Greenhouse Gases

With the bill for a Climate Act (The Danish Government, 2020) agreed in the Danish Parliamant in June 2020 and the December 2019 agreement behind the bill (The Danish Government et al, 2019), Denmark has decided to reduce emissions of greenhouse gases by 70% in 2030 compared with 1990 emissions. According to the Climate Act, a new greenhouse gas reduction target for the year 2025 shall be agreed.

The Climate Act establishes an annual cycle to ensure ongoing follow-up on whether climate efforts are supporting the fulfilment of the targets in the Climate Act.

According to the Climate Act annual cycle, from 2021 Denmark's Climate and Energy Outlook report will review the progress made towards reaching the climate targets each April. Denmark's Climate and Energy Outlook reports will therefore be part of this new cycle from 2021.

DCEO20 focuses on the 70% greenhouse gas reduction target for 2030 in the Climate Act and presents the status for and projections of Denmark's greenhouse gas emissions in 2025 and 2030 in accordance with the UN's methodologies.

The DCEO20 explores Denmark's emission sources and provides detailed insight into the projected development of Denmark's emissions up to 2030 in the absence of any new measures.

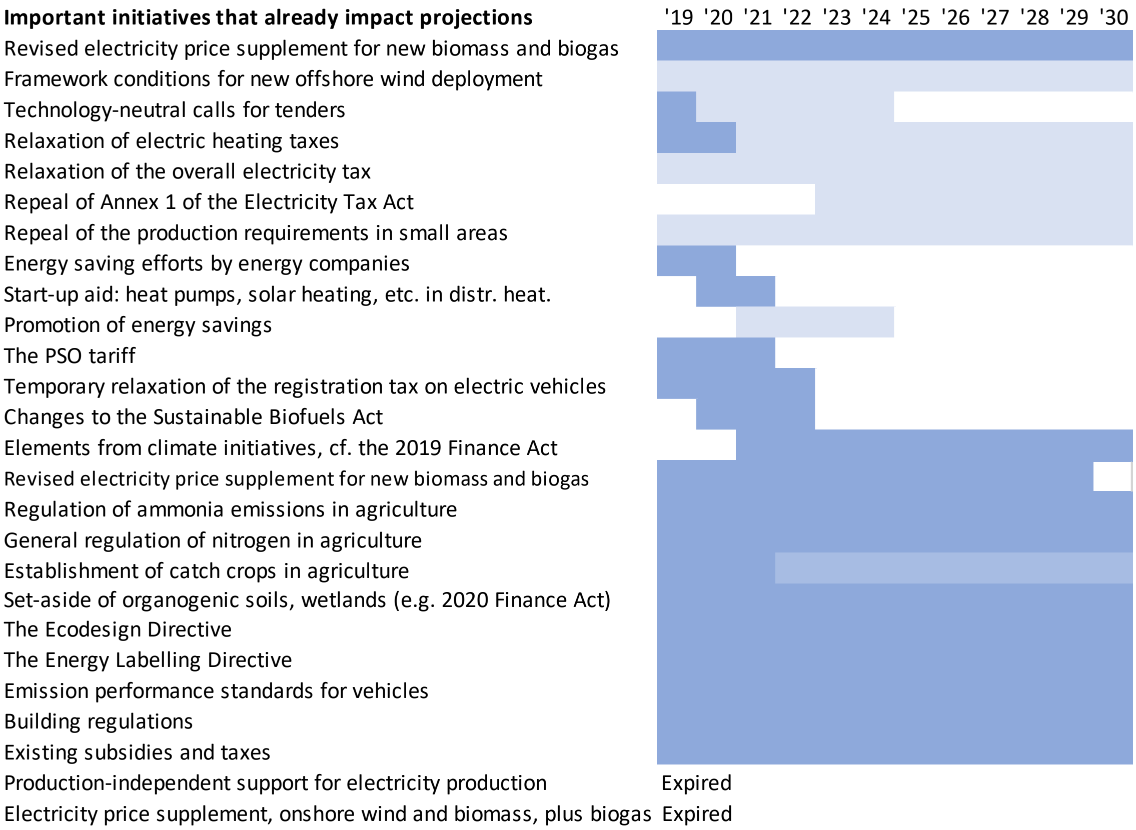

Figure 1: Temporal scope of the most important climate and energy measures that already have an impact on the projection. Light blue areas indicate that measures are part of the 2018 Energy Agreement. The regulation is described in more detail in Appendix 3.

1.2 What Are Greenhouse Gases, and How Are Emissions Calculated?

Calculations of greenhouse gas emissions in Denmark's Climate and Energy Outlook report follow international standards originating from the United Nations Framework Convention on Climate Change. Pursuant to the Danish Climate Act, the calculation of emissions in connection with assessing the status for target fulfilment are based on the same methodology.[1]

[1] In practice, the Danish Energy Agency presents a basis that allows for calculating emissions both according to the UN calculation methodology and the national calculation methodology used in Danish statistics, for example. The difference between the two methodologies concerns, for example, international air transport, bunkering, Greenland and the Faeroe Islands, and pleasure craft. The Danish Energy Agency also calculates the consumption of biomass.

DCEO20 presents the calculation of greenhouse gas emissions according to the following sectoral breakdown: • Energy utilities and space heating (Chapter 3). • Industry and services (Chapter 4) • Waste and wastewater (Chapter 5) • Transport (Chapter 6) • Agriculture, forestry and other land use (Chapter 7)

All emissions of greenhouse gases from Danish territory are included in the calculation, including emissions from consumption of fossil fuels, industrial gases and industrial processes, waste treatment, emissions from agriculture and emissions and removals stemming from forestry and other land use activities, primarily in agriculture. CO_2 emissions from consumption of biomass (burning of wood chips and wood pellets, for example) is considered greenhouse-gas-neutral where it is consumed and are therefore not included.[2] Furthermore, emissions from international shipping and air transport are not included, as these sectors are dealt with under separate UN agreements with their own climate targets.

In short, the term greenhouse gases covers all gases that contribute to the greenhouse effect. An increase in the concentration of greenhouse gases in the atmosphere increases the greenhouse effect, and this can cause global mean temperature rise and global climate change.

Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated greenhouse gases (F gases). The gases have different greenhouse effects that are converted into CO2 equivalents (abbreviated CO2-eq.) based on their Global Warming Potential (GWP) over a 100-year time period relative to CO_2.

Text box 1: Important greenhouse gases, their sources and CO2 equivalents.

CO_2 (carbon dioxide)	For example, from combustion of fossil fuels such as coal, oil, and natural gas, and as the release of stored carbon as CO_2 from soils and forests. GWP: 1 CO2-eq.
CH_4 (methane)	From organic processes such as the digestion system of animals and composting of organic waste. GWP: 25 CO2-eq.

[2] Pursuant to the UN methodology, CO_2 from consumption of biomass should be calculated and reported under a so-called memo item and these emissions have therefore not been included in the national inventory. This is because the emissions are included at an earlier stage, i.e. when carbon stored in biomass is removed from fields and forests. This removal and the related emissions are calculated and included in the emission inventory of the country from where the biomass originates.

N_2O (nitrous oxide)	From nitrogen conversion, for example from manure applied to soils. GWP: 298 CO2-eq.
F gases	From chemical processes, such as refrigerants in cooling systems and when producing plastic foam. GWP: for example 22,800 CO2-eq. (SF6)
International guidelines on greenhouse gas inventories undergo regular changes when new knowledge becomes available due to research etc. This also applies to knowledge about the respective GWP values of greenhouse gases, and these values usually changes at the earliest opportunity after new research results have been published by the UN Intergovernmental Panel on Climate Change (IPCC) in one of its Assessment Reports (AR). The international guidelines include requirements for recalculation of existing annual greenhouse gas inventories going back to 1990, whenever such changes to methodology are introduced. This will prevent the time series for greenhouse gas emissions becoming inconsistent due to changes in GWP. Up to and including the 2022 report (which covers the period 1990-2020), the above GWP values from IPCC AR4 (2007) should be used. In the Paris Agreement, it was decided that the GWP values from IPCC AR5 (2013) are to be used from 2024 and onwards, at the latest.	

Emissions of greenhouse gases are not measured, but are calculated based on emission activity data, such as fossil fuel consumption, number of livestock in agriculture, land use and plant growth, decay and harvest.

The emission factors are regularly adjusted when new knowledge emerges. When this happens, not only the projections, but also the historical figures and the statistics are adjusted to produce a more correct presentation of historical emissions. This means that projections could vary solely on the basis of altered emission factors.

Text box 2: Baseline year emissions (1990) adjusted upwards by 2 million tonnes compared to last year's outlook.

Baseline year emissions (1990) are adjusted upwards by 2 million tonnes compared to last year's outlook. Among other things, this is because of an error related to the calculation of the total area of organic soils with a primary soil organic carbon content above 6%. The area of organic soils and emissions from these soils in 1990 is consequently adjusted upwards by 29%, from 4.7 million tonnes CO2-eq. to 6.1 million tonnes CO2-eq. Similarly, 2017 emissions are adjusted upwards from 3.4 million tonnes CO2-eq. to 4.7 million tonnes CO2-eq. Upward adjustments are made for all statistical years and in projection models. Moreover, emissions from agriculture are adjusted upwards due to a revised methane emissions factor for livestock manure.

1.3 How Has DCEO20 Been Prepared?

DCEO20 was prepared by the Danish Energy Agency, assisted by an inter-ministerial monitoring group comprising: the Ministry of Climate, Energy and Utilities; the Ministry of Finance; the Ministry of Taxation; the Ministry of Transport and Housing; the Danish Transport, Construction and Housing Authority; the Ministry of Environment and Food; the Danish Agricultural Agency; the Danish Environmental Protection Agency; the Danish Ministry of Industry, Business and Financial Affairs; and the Danish Nature Agency.

In order to qualify the methodological and technical-economic basis for the model analyses in DCEO20, the Danish Energy Agency has moreover consulted several experts and institutions. The Danish Energy Agency is responsible for the energy balance and for the projections of energy-related emissions, while the Danish Centre for Environment and Energy (DCE) at Aarhus University is responsible for the projections of non-energy-related emissions.

TheDCE bases its projections of emissions from agriculture on data from the Department of Food and Resource Economics (IFRO, University of Copenhagen) in the form of projections of the number of livestock in agriculture and data on expected future land use (types of crops, for example). The DCE bases its projections of emissions and removals from carbon stored in forests on a calculation by the Department of Geosciences and Natural Resource Management (IGN) at the University of Copenhagen. Based on the Danish Energy Agency's projections for the energy balance and on data from the Danish Environmental Protection Agency, the DCE is also responsible for projecting other non-energy-related emissions, including F gases, and emissions from industrial processes, biogas production, extraction of oil and natural gas, and waste.

Figure 2 illustrates the overall model and data elements included in DCEO20.

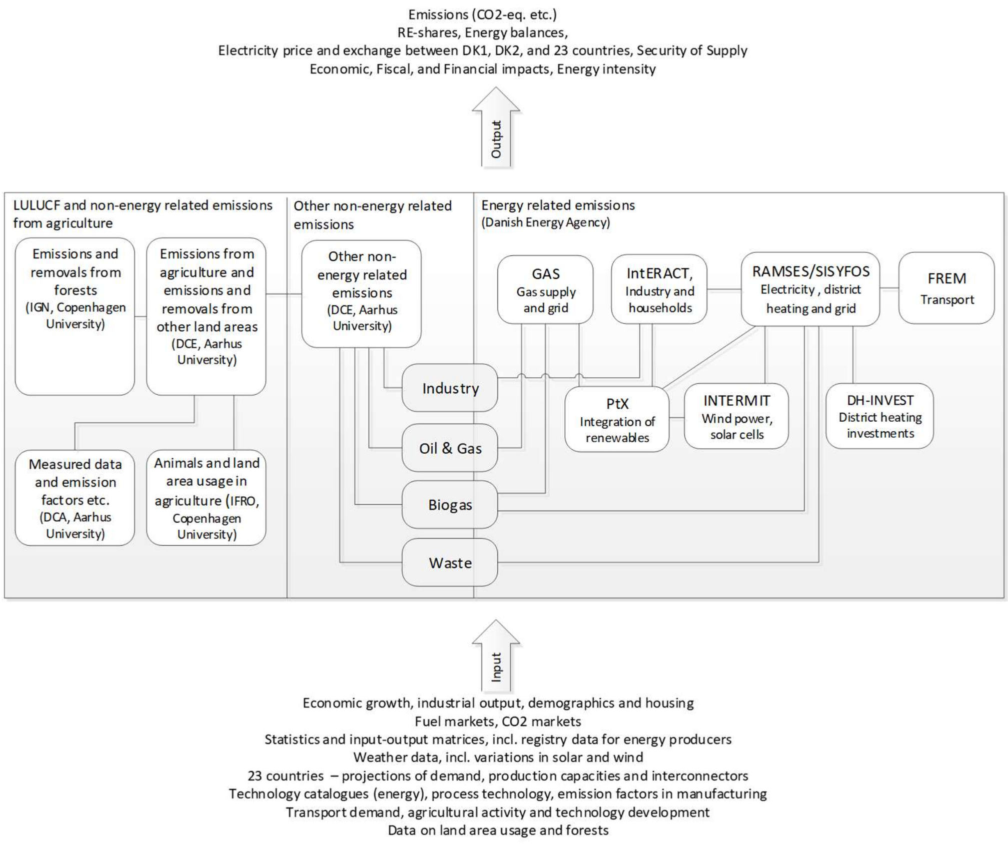

Figure 2: Denmark's Climate and Energy Model - the Danish Energy Agency's integrated model and data platform. [3] Some of the detailed assumptions and methods behind DCEO20 are described in reports from the Danish Centre for Environment and Energy (DCE), the Department of Food and Resource Economics (IFRO), the Danish Centre for Food and Agriculture (DCA) and the Department of Geosciences and Natural Resource Management (IGN).

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[3] See the Danish Energy Agency website for descriptions and documentation of the submodels (Danish Energy Agency, 2019h).

1.4 Sensitivities and Uncertainties

DCEO20 presents a baseline scenario up to 2030 using a central set of assumptions, which the Danish Energy Agency assesses to be the most probable on the basis of current knowledge and in the absence of any new measures.

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

The projections look ten years ahead, and the result may vary from year to year regardless of any measures. The general methodological uncertainty is reinforced by considerable uncertainty in exogenous variables.

At the end of each sectoral chapter, selected significant uncertainties are described.

This year, there is particular uncertainty linked to the COVID-19 pandemic and the rate at which the Danish economy will return to relatively normal conditions. In addition to uncertainty regarding how the pandemic will develop, economic recovery also depends on developments in the international economy, fuel prices and on business and consumer confidence. The projections are based on expectations about fuel prices and economic growth prior to COVID-19, because it is not yet possible to quantify these uncertainties. The focus of DCEO20 has been narrowed to the years 2025 and 2030 in order to reflect that future emissions and energy consumption are exceptionally uncertain.

1.5 Background Figures and Materials Online

The detailed assumptions behind the projections, including assumptions concerning deployment of onshore wind, solar PV and biogas, are available on the Danish Energy Agency website (Danish Energy Agency, 2019d).

2 The Overall Picture

In 2018, Denmark emitted 54.8 million tonnes CO2-eq.[4] This means that, in 2018, Denmark's total emissions of greenhouse gases were reduced by 29% compared to 1990.[5]

In the absence of any new measures, emissions are expected to be reduced to 43.1 million tonnes in 2030, corresponding to a reduction of 44% compared with 1990. With regard to the target of reducing emissions by 70% by 2030, a reduction effort of 26 percentage points remains, which corresponds to 20 million tonnes CO2-eq.

Table 1 summarises the progress made towards the reduction and supporting targets.

Table 1: Current status of Denmark's primary targets and commitments in the climate and energy area. The EU obligation for emissions outside the ETS sector is not assessed. A subsequent assessment will be prepared later.

Target	Statutory / agreement basis	Status in the absence of any new measures
70% reduction of national greenhouse gases incl. LULUCF* in 2030 relative to 1990	The Climate Act (Danish Government, 2020) and the agreement on the Climate Act (Danish Government et al, 2019)	44% reduction in 2030 A reduction effort of 20 million tonnes CO2-eq. remain.
Phase-out of coal for electricity production up to 2030	The 2018 Energy Agreement (Ministry of Energy, Utilities and Climate, 2018b)	Will be reached.
55% renewables share in total energy use in 2030	The 2018 Energy Agreement (Ministry of Energy, Utilities and Climate, 2018b) supported by the Renewables Energy Directive's target for national contributions to an overall EU renewables share of 32% in 2030 (European Commission, 2018)	Will be reached.
14% renewables share in transport in 2030	Renewable Energy Directive (European Commission, 2018)	Will be reached. Underlying 3.5% target for second-generation biofuels in 2030 has not been assessed.
EU obligation for emissions of greenhouse gases outside the ETS sector (non-ETS) in 2030	The Effort Sharing Regulation (EU, 2018)	Has not yet been assessed.

***LULUCF is an abbreviation for emissions and removals from Land Use Land Use Change and Forests.**

Historically, energy utilities and space heating (Chapter 3) – i.e. the electricity and heating area - have made significant contributions to reducing emissions and will continue to do so up to 2030. In 1990, the sector emitted 31 million tonnes CO2-eq., corresponding to 40% of total emissions for 1990.[6] In 2030, despite increasing electricity production for export, the sector is expected to emit 2.3 million tonnes CO2-eq. corresponding to 5% of total emissions in 2030.

Emissions in industry and services (Chapter 4) will decrease up to 2030, whereas energy consumption in industry and services (excluding the oil and gas industry) will increase by 1.9% annually. Energy-related emissions in industry and services (excluding the oil and

[4] The most recent year for which final energy statistics (Danish Energy Agency, 2019e) and an emissions inventory statement (European Environment Agency, 2020b) are available. The projections operate with a statistical deviation when adding up the emission inventory's underlying figures. This deviation is due to rounding of values, among other things. The statistical deviation was 0.2 million tonnes CO2-eq in 2018.

[5] The UN base year for Denmark's emissions inventory.

[6] Minimum estimate because it is not statistically possible to break down business sector emissions by use.

gas industry) will fall by 0.5% annually, while emissions from industrial processes will fall by 0.9% annually. Emissions from the oil and gas industry will reflect declining production. Note that emissions related to electricity consumption in industry and services are included in Chapter 3.

Waste and wastewater (Chapter 5) are expected to reduce emissions by 5% up to 2030 compared with 2018. The reduction is primarily due to reductions in emissions from landfills and less organic waste being sent to landfills.

Historically, the transport sector (Chapter 6) has shown a tendency towards increasing emissions, and this changes only marginally in the projection. In 2030, the sector is expected to emit almost 14 million tonnes CO2-eq., which is 15% higher than total emissions for 1990. An expected increase in the sale of electric cars and plug-in hybrid cars, after 2025 in particular, will only have a slight impact on emissions before 2030 due to the long average service life of cars of around 15 years.

For agriculture, forestry and other land use (Chapter 7), a distinction is made between emissions of primarily methane and nitrous oxide from agricultural production on one hand, and emissions and removals of CO2 in forests and other land (the so-called LULUCF sectors) on the other.

Historically, an emission reduction of 16% has been realised in agricultural production from 1990 until today. Up to 2030, emissions from agricultural production are expected to remain at more or less the same level as today.

Emissions from forests and other land use are particularly uncertain, with considerable annual fluctuations. In 1990, the net removal by forests was 0.5 million tonnes CO2-eq. Up to 2030, forests are expected to have annual net emissions of 0.1 million tonnes CO2-eq. Net emissions from other land are expected to fall from 7.0 million tonnes CO2-eq. in 1990 to 5.2 million tonnes CO2-eq. in 2030. This reduction is primarily due to increased yields, establishment of catch crops and re-establishment of wetlands on organic agricultural soils.

Figure 4 shows the expected breakdown by sector of total emissions in 2030. Agriculture, forestry and other land use are expected to emit 16.1 million tonnes CO2-eq. Transport is expected to emit 13.7 million tonnes CO2-eq. Industry and services are expected to emit 8.6 million tonnes CO2-eq., while the utilities sectors are expected to emit a total of 4.6 million tonnes CO2-eq.

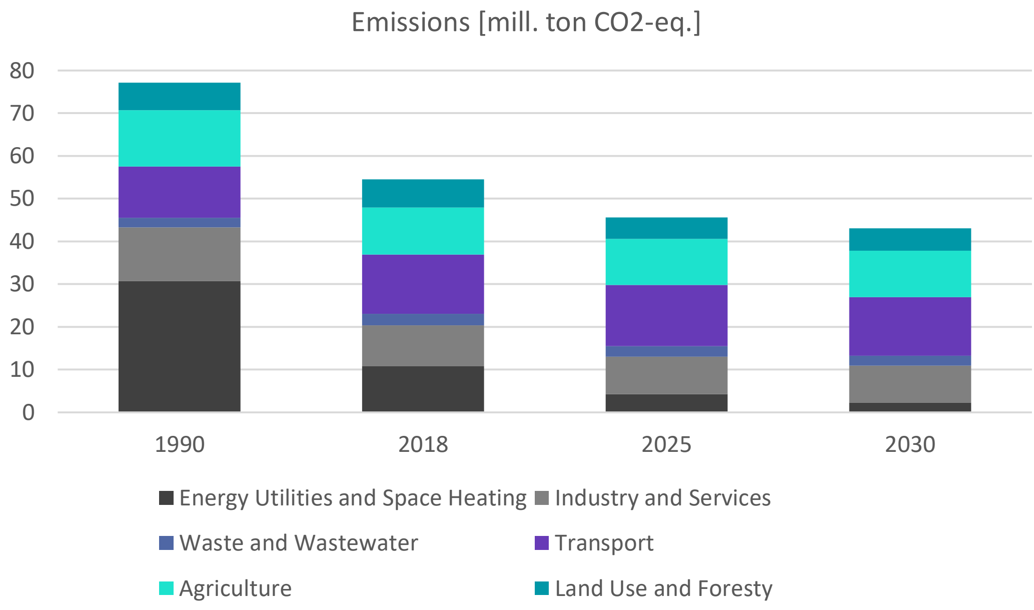


Figure 3: Total emissions by sector 1990-2030 [mill. tonnes CO2-eq.]. No energy statistics are available for historical emissions in industry and services by use.[7]

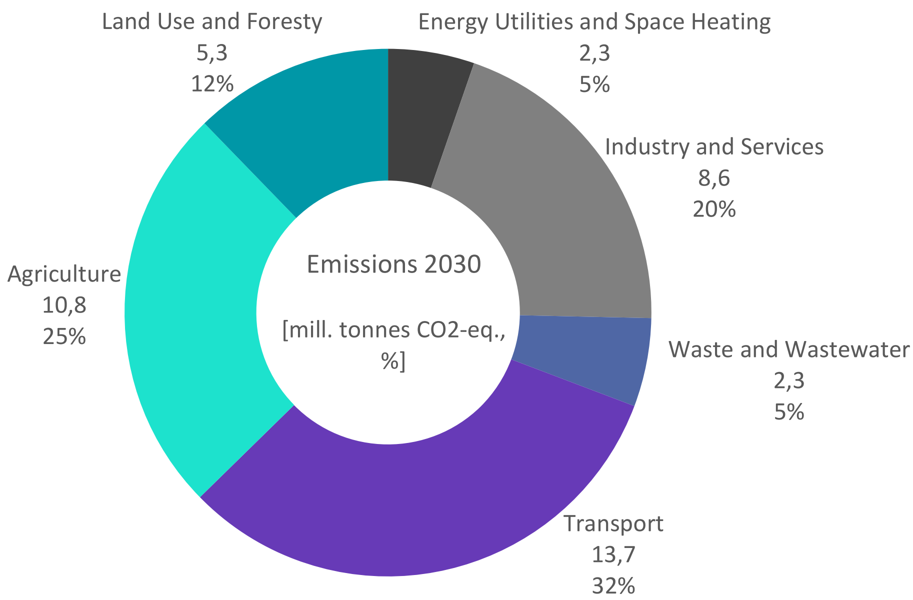
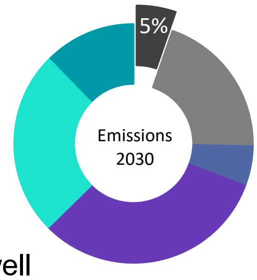


Figure 4: Total emissions in 2030 by sector [mill. tonnes CO2-eq., %].

[7] No energy statistics are available for emissions in industry and services by use. Energy consumption in industry and services for space heating is categorised under "Industry and services" in 1990, while in other years it is categorised under "Energy Utilities and space heating". The sum of emissions is correct. For 2018 and onwards, space heating in industry and services is based on a survey of energy consumption (heating or industrial processes) (Hedelund Sørensen, 2015).



3 Energy Utilities and Space Heating

Electricity and heat supply to Danish households and businesses from energy utilities supplying electricity, district heating and gas from centralised grids as well as supply of oil to individual heating equipment is expected to emit 2.3 million tonnes CO2-eq. in 2030, accounting for 5% of total emissions.

Figure 5 shows that in 2018, electricity and heating accounted for 10.8 million tonnes CO2-eq., corresponding to 20% of total emissions for the year. Of this, electricity and district heating utilities emitted 7.8 million tonnes CO2-eq., while energy use for space heating by households and businesses emitted 3.0 million tonnes CO2-eq.

Electricity and district heating utilities are expected to reduce emissions from 30.7 million tonnes CO2-eq. in 1990 to 0.5 million tonnes CO2-eq. in 2030. Among other things, this reduction will be the result of a transition from coal-fired electricity and district heating production to other sources. Coal phase-out is expected by 2028. See Chapter 5 with regard to emissions from waste incineration.

For households and businesses not using district heating, emissions from heating are expected to fall from 6.4 million tonnes CO2-eq. in 1990 to 1.8 million tonnes CO2-eq. in 2030. This reduction in emissions is driven by an increasing share of bio natural gas (SNG) in the gas supply as well as further electrification of heating, where heat pumps will continue to replace oil-fired and gas-fired boilers.

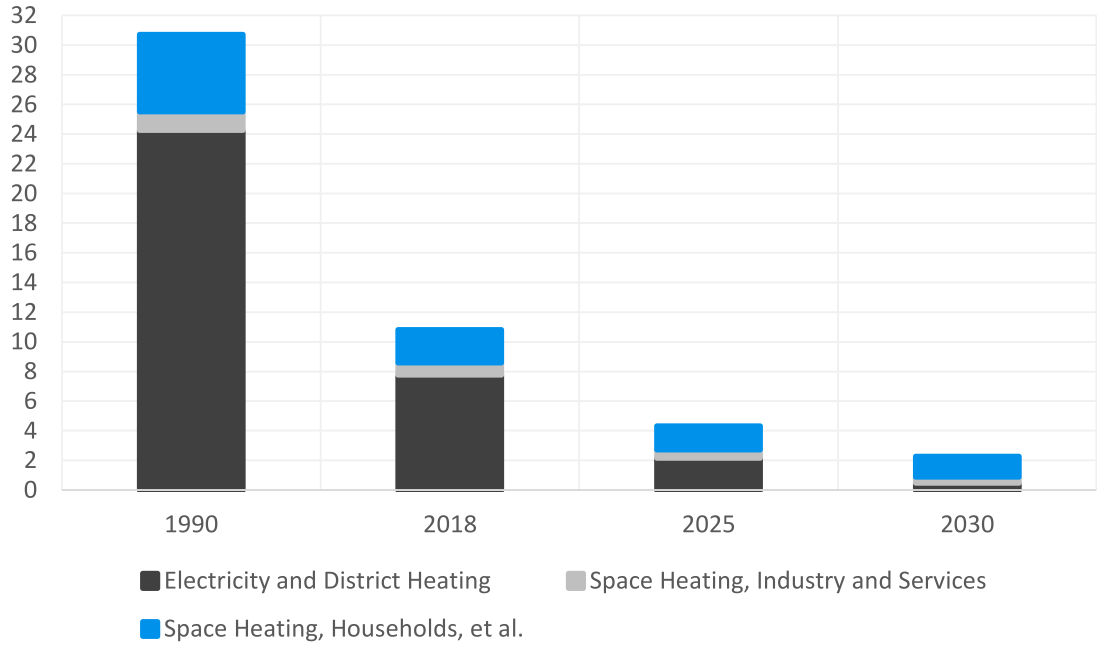


Figure 5: Sector emissions “Energy Utilities and space heating” 1990-2030 [mill. tonnes CO2-eq.]. Energy consumption for space heating in industry and services is categorised under "Industry and services" in 1990.

3.1 Energy utilities

The development in the supply of electricity, district heating and gas is characterised by a phase-out of coal and by significant renewable energy deployment.

3.1.1 Coal Will Be Phased Out Before 2030

Figure 6 illustrates that coal-based supply will be phased out in the period up to 2030. With the expected phase-out of coal at Nordjyllandsværket at the end of 2028, and the recent decision to phase out coal at Fynsværket in 2022 (Odense Municipality, 2020), Energy Utilities' use of coal is expected to be fully phased out before 2030.[8]

The transition away from coal-based supply has been driven by a combination of incentives (including subsidy schemes for transitioning to biomass, tax exemption for heat from biomass and gradual relaxation of taxes on consumption of electricity for heating) and targets to phase out coal set by municipalities and private companies.

Furthermore, energy utilities' use of gas is expected to be gradually phased out and to be reduced by 50% in 2030 compared with 2018. This development is driven by better opportunities for alternative heat production and less favourable conditions for gas-based electricity production, partly due to low electricity prices and removal of the basic amount. It is expected that gas will primarily be used in periods of high electricity prices and during peak-load periods in electricity and district heating supply. Instead, heat production will be based on biomass plants, heat pumps and solar heating, while electricity production will come primarily from wind power and solar PV.

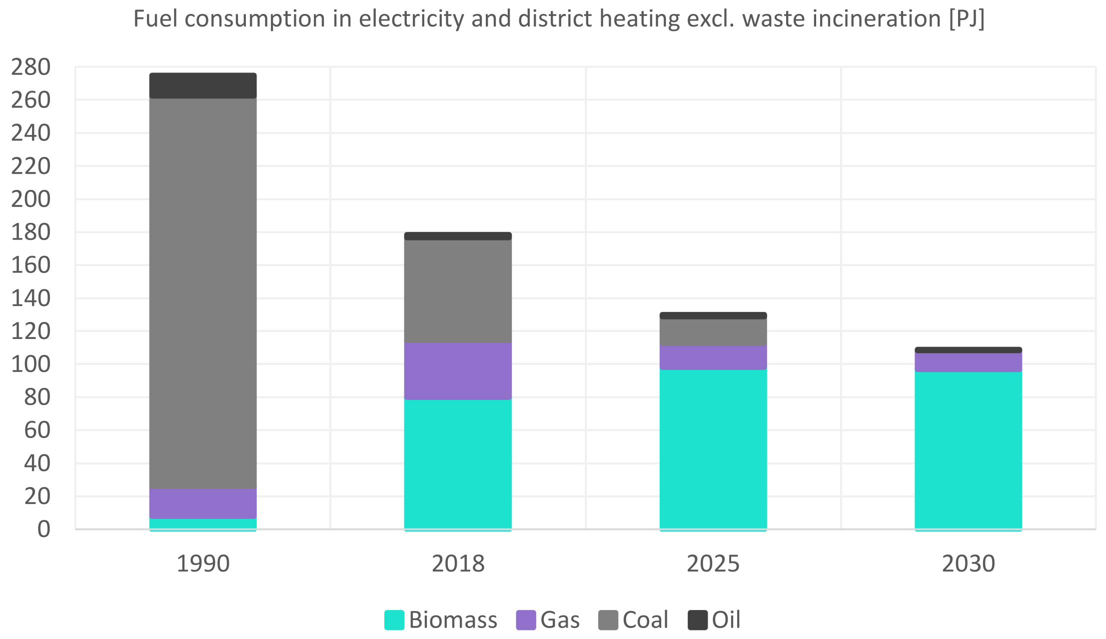


Figure 6: Consumption of oil, coal, gas and solid biomass for production of electricity and district heating 1990-2030 [PJ]. Consumption of waste is included under Chapter 5.

[8] It is expected that in 2030, some power stations will retain an option for operation based on coal to cover any reserve load, but such use is assumed to be very limited.

3.1.2 Renewable Energy Will Take Over Electricity Supply

Figure 7 shows that the renewables-based electricity supply capacity is expected to rise to 12 GW up to 2030; this is twice the capacity compared with 2018. Deployment of 4,300 MW offshore wind, 5,500 MW solar PV and 1,700 MW onshore wind is expected from 2018 to 2030.[9]

The expected offshore wind deployment is a result of decisions already made, and several offshore wind farms are under construction. From 2018 to 2030, seven new offshore wind farms will be constructed and commissioned.[10] Furthermore, deployment of almost 700 MW of wind power is expected under the "Open-Door" scheme.[11] Overall, offshore wind (including nearshore wind turbines) is expected to account for more than 40% of Danish electricity production in 2030.

The expected deployment of solar PV is based on knowledge gathered from municipalities and companies by the Danish Energy Agency about projects already far into the preparation phase. Furthermore, the projections are based on an expected continued technological development that will help render large ground-mounted solar installations lucrative, as well as an expectation that the municipalities will make land available as required. With the estimated expansion of capacity, solar PV will account for almost 15% of Danish electricity production by 2030.

Bilateral power purchase agreements (PPAs) with large electricity consumers and technology-neutral calls for tender currently contribute to the economic viability of solar PV projects. The large-scale deployment of solar PV increasingly affects the settlement price for solar PV installations producing power in the same hours, and this could affect the market price of electricity in the long term. The uncertainty with respect to the settlement price for large solar PV installations could affect the development, because it is uncertain how the financial market will respond. For example, this applies to the market for PPAs/GOs (K2 Management for the Danish Energy Agency, 2019).

The onshore wind capacity will increase by approx. 1,700 MW, as old wind turbines are replaced by new and more efficient turbines. Consequently, there will be a slight decline in the number of wind turbines, from 4,200 today to 3,900 in 2030. The more efficient turbines will produce 50% more electricity from onshore wind than today. It is expected that onshore wind can be established on market terms in the future, but deployment depends on access to land and the possibility of obtaining approval from municipalities.

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[9] The capacities are for the individual technologies, and annual electricity production per MW is different for the different technologies.

[10] Covers Horns Rev 3 (400 MW), Kriegers Flak (600 MW), North Sea (north) and North Sea (south) (350 MW), Thor (800-1000 MW), and two additional wind farms with a total capacity of 1800-2000 MW under the 2018 Energy Agreement which have not been specified.

[11] The expected development for wind turbines under the "Open-Door" scheme is estimated on the basis of applications received by the Danish Energy Agency for which a preliminary investigation licence has been granted.

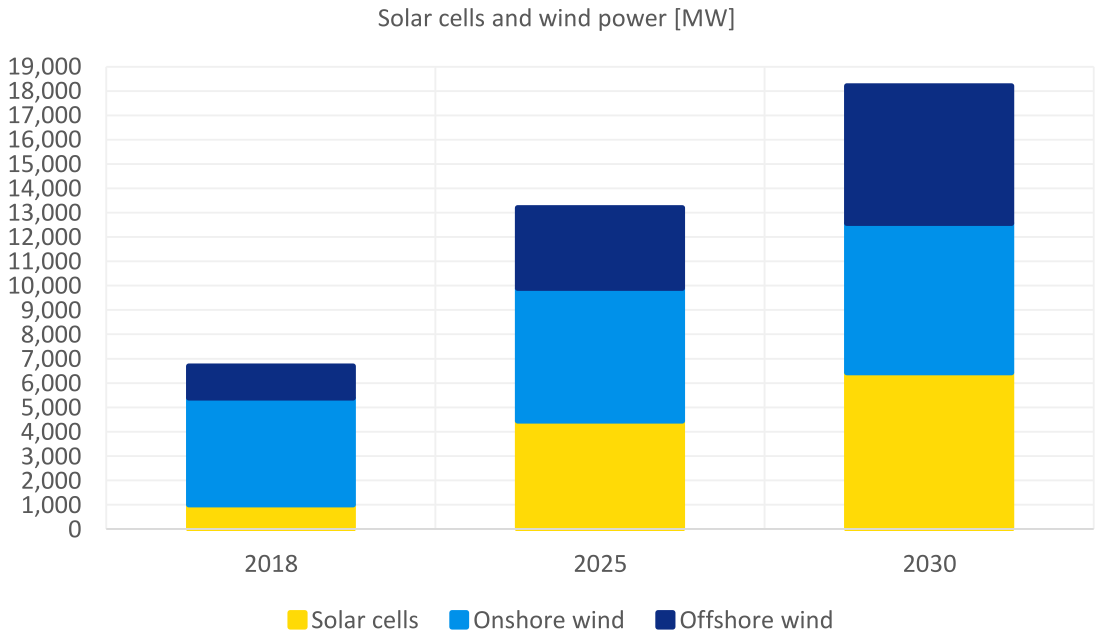


Figure 7: Electricity supply capacity for solar PV, onshore wind and offshore wind 1990-2030 [MW].

3.1.3 More Electrification of District Heating

Figure 8 shows that the heat supply capacity will see a deployment of almost 800 MW from large electric heat pumps up to 2030. Heat pumps will produce 16 PJ of district heating in 2030, corresponding to 12% of district heating consumption. The deployment is in progress, and 80 installations are in the planning phase or have been established.

The deployment of large electric heat pumps is driven by relatively low operating costs in particular, partly due to a reduction of the tax on electric heating and phase-out of the PSO tariff, leading to lower costs for using electricity for district heating production. At the same time, the capacity payment for a number of small-scale natural gas plants (the basic amount) has been removed, and this has a negative impact on the economic viability of plants relying on natural gas as baseload.

It is expected that heat pumps, in particular, will be used in small-scale district heating areas that rely on gas. The projection includes the expected impact of exemptions from the fuel obligation (obligation to buy gas) and CHP production (requirement for co-generation of electricity and district heating). Deployment of large heat pumps is expected in large-scale district heating areas in Esbjerg-Varde, Odense and Aalborg. These areas have been granted an exemption to establish heat pumps in connection with phasing out of existing coal-fired production. In other major cities, establishing heat pumps on a larger scale is not possible under current regulation. District heating supply is expected to be based primarily on biomass in these areas.

Electric boilers represent a relatively large heat capacity in comparison to heat pumps, but operate with a lower capacity factor. The primary purpose of installing electric boilers is to exploit the opportunities for income on the ancillary services markets, including the regulation of the link between Denmark and Germany (Energinet, 2020), while also replacing oil-based and gas-based peak and reserve capacities.

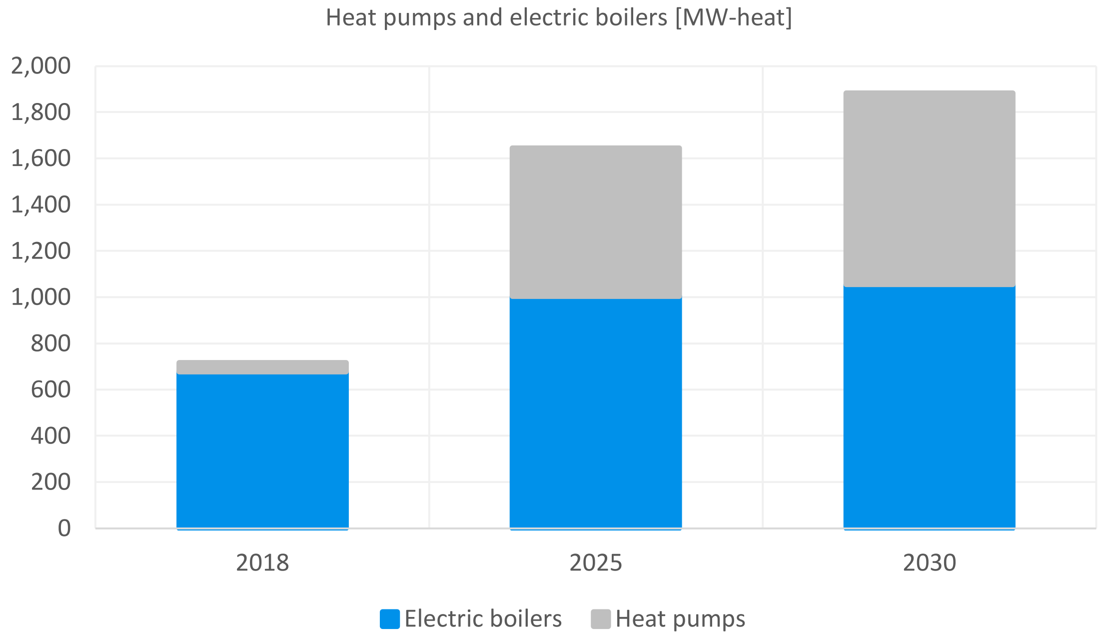


Figure 8: Heat supply capacity for large electric heat pumps and electric boilers 1990-2030 [MW heat].

3.1.4 More Biogas Ensures More Green Gas in the Grid

Biogas is used for electricity and heat production, direct consumption in industry, and is upgraded to bio natural gas (SNG), which is distributed with natural gas via the natural gas grid and the city gas grid. Figure 9 shows that the consumption of mains gas increased up to 2018, but is expected to fall up to 2030, whereas production of SNG will more than quadruple from 5 PJ in 2018 to 22 PJ in 2023. Moreover, some biogas will be produced for direct use, primarily in electricity and heat production. Total production of biogas is thus expected to increase to just over 30 PJ in 2030.

Since total consumption of mains gas is decreasing, and production of bio natural gas is increasing, the renewables share of mains gas will increase to 30% in 2030 (Chapter 8).

The production of biogas has been increasing since the introduction of the subsidy schemes in connection with the 2012 Energy Agreement (Ministry of Energy, Utilities and Climate, 2012). The possibility of submitting new applications under the existing support schemes ended on 1 January 2020, although there remains an option to apply for exemption for installations under construction, provided certain criteria are met (Danish Energy Agency, 2020b). The final deadline for applications for support is 1 July 2020 (Danish Energy Agency, 2020a), and the trend in biogas volumes is therefore based on a preliminary estimate of the number of installations likely to receive support during the projection period (including exemptions) and an estimate of their expected production. However, the estimated amount of biogas ascribed to the open exemption scheme is very uncertain.

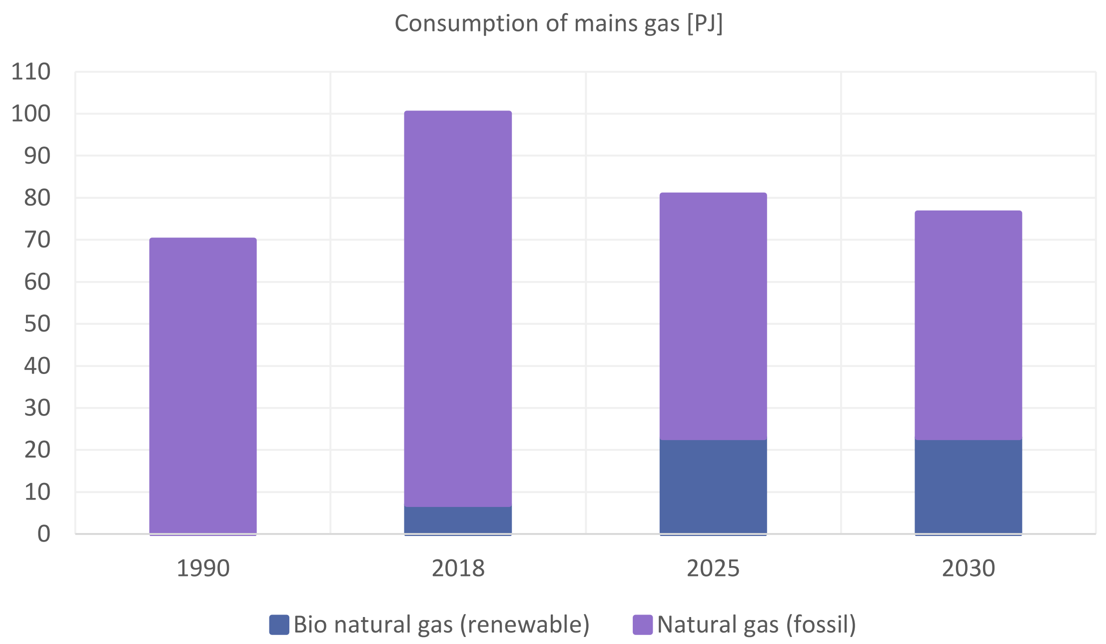


Figure 9: Consumption of natural gas (fossil) and bio natural gas (renewable SNG) 1990-2030 [PJ].

3.2 Space Heating - Falling Consumption of Oil and Gas

Figure 10 shows that total energy consumption for providing heat to businesses and households will fall by 0.3% annually between 2018 and 2030.

District heating, gas and biomass are expected to continue to play a major role, while oil-based heating will be reduced, as this type of heating becomes more expensive. Heat pumps, in particular, will play a greater role. Household consumption of biomass, including wood pellets, is expected to have peaked by 2018 and will likely follow a downward trend towards 2030.

The energy saving effort under the 2018 Energy Agreement (Ministry of Energy, Utilities and Climate, 2018a) expires in 2024, and energy-efficiency improvements aimed at reducing the heating demand of buildings in businesses and households will not have a considerable effect toward the end of the forecasted period.

CO_2 emissions from heating are mostly from the consumption of oil and gas. Figure 10 shows that the reduction in emissions from heating is contingent on energy consumption from oil- and gas-fired boilers falling by 2.3% annually up to 2030. Bio natural gas (SNG) blending will have particular influence on the fall in emissions from gas consumption (see Chapter 3.1.4 and Chapter 8.2).[12]

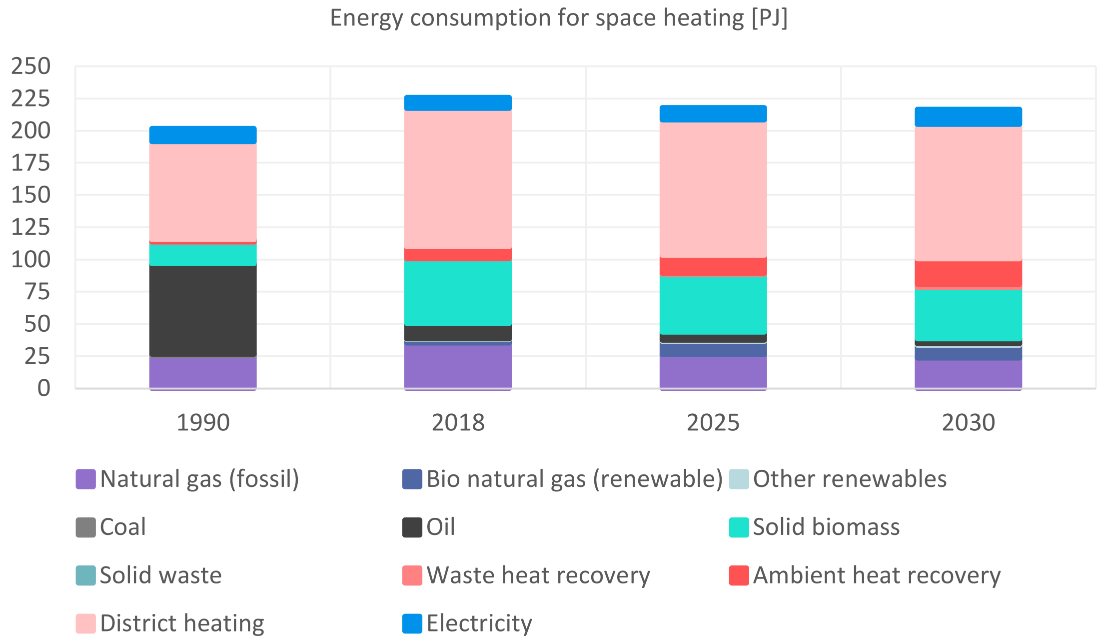


Figure 10: Energy consumption for space heating 1990-2030 [PJ]. Waste heat is recovered from other energy consumption and is per definition not included in the definition of final energy consumption. Energy consumption for space heating in industry and services is categorised under "Industry and services" in 1990, see footnote 7.

[12] Final energy consumption figures are climate-adjusted, whereas emissions are actual, historical emissions.

3.3 Sensitivities

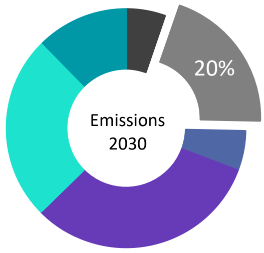
Projections of electricity and district heating supply, and projections of production of renewable energy gases and heating are generally sensitive to the following assumptions:

- Developments in electricity consumption, including, in particular, electricity consumption by data centres
- Developments in fuel prices and carbon prices
- Domestic deployment of onshore wind, in particular the rate with which older wind turbines will be decommissioned and the availability of locations for new turbines
- Domestic deployment of commercial solar PV (ground-mounted solar farms)
- The rate at which oil- and naturalgas-fired boilers re phased out from heat supply
- The renewables share of mains gas

The projected developments are characterised by expected reductions in emissions up to 2030, as a result in particular of known investment decisions related to phasing out coal-fired electricity and district heating production and offshore wind deployment.

The projected emissions from electricity and district heating supply in 2030 are characterised by lower uncertainty than other sectors. Corresponding with the transition to renewable energy, emissions will become less sensitive to climate and weather conditions. In 2030, fluctuations in climate and weather could mean fluctuations in the range of +/- 0.2 million tonnes CO2-eq., as opposed to +/- 5 million tonnes CO2-eq. previously.

However, the uncertainties linked to developments will still be significant for other aspects of the energy system, including import/export of electricity, electricity prices in the spot market and the use of biomass.



4 Industry and Services

The sector is expected to emit 8.6 million tonnes CO2-eq. and will therefore account for 20% of total emissions in 2030.

Figure 11 shows that the sector emitted 9.6 million tonnes CO2-eq. in 2018, corresponding to 18% of total emissions. The share relative to total emissions will therefore be slightly higher in 2030, although absolute emissions are lower.

Emissions by industries and services include energy-related emissions resulting from energy consumption for production processes, including industrial process heat and internal transport. Furthermore, emissions from industrial production processes are also included, while emissions from heating supply for buildings and other space areas in the business sector are included in Chapter 3. Finally, emissions from auto-consumption and flaring in the oil and gas industry are also included.

In 2030, the energy-related emissions (excluding the oil and gas industry) are expected to account for 54% of the sector's emissions, the oil and gas industry is expected to account for 25%, while industrial processes are expected to account for 21%. The energy-related emissions (excluding the oil and gas industry) will fall by 0.5% annually up to 2030, even as energy consumption increases by 1.9% annually up to 2030. This is due to an increasing share of green gases in the gas grid, and to the gradual introduction of heat pumps for process heat applications

Emissions from industrial processes will fall from 2.0 million tonnes CO2-eq. in 2018 to 1.8 million tonnes CO2-eq. in 2030, due to a reduction in emissions of F gases. Emissions from auto-consumption and flaring in the oil and gas industry will fall from 2.5 million tonnes CO2-eq. in 2018 to 2.2 million tonnes CO2-eq. in 2030, due to declining and more efficient production.

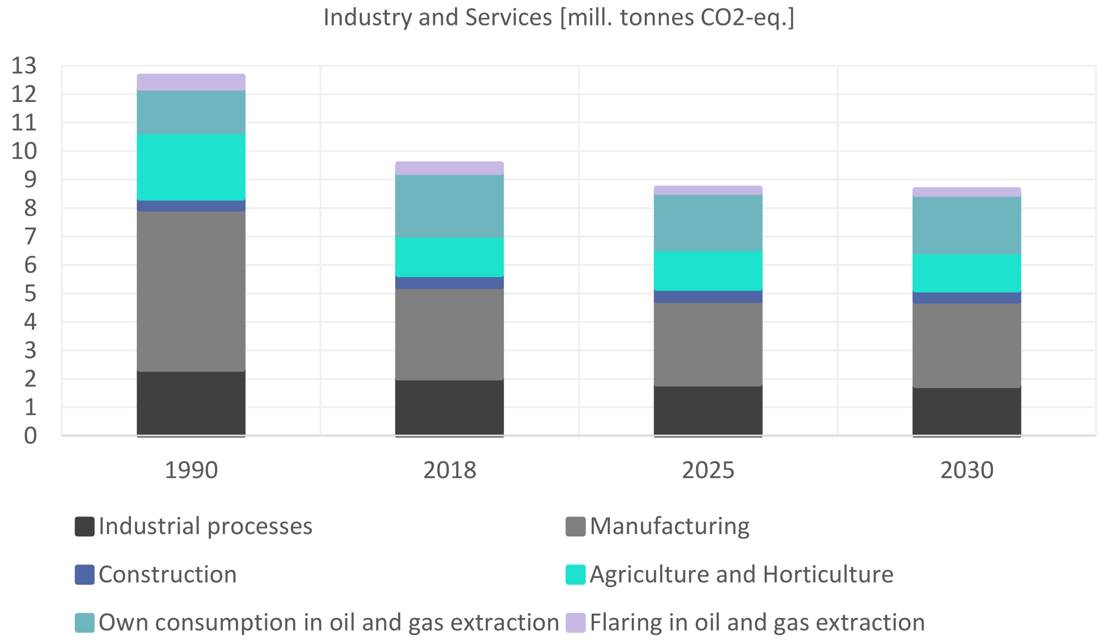


Figure 11: Emissions in industry and services by subgroups 1990-2030 [mill. tonnes CO2-eq.] Energy consumption for space heating in industry and services is included in 1990 figures, see footnote 7.

4.1 Continued Consumption of Oil, Coal and Gas

Energy consumption in industry and services for production processes, lighting and equipment, and internal transport will account for 29% of total final energy consumption in 2030.

Figure 12 shows that the sector is expected to consume fossil fuels amounting to 65.9 PJ in 2030, which means that energy-related emissions will total 4.7 million tonnes CO2-eq. The fossil fuels will go to process heat and internal transport. Internal transport is commercial transport by vehicles and machinery such as construction machines, tractors, combine harvesters, fishing boats and trucks. Energy consumption for other commercial transport, such as vans, is included in energy consumption by the transport sector (Chapter 6).

The falling share of fossil fuels is due mostly to an expected increase in the share of renewables in mains gas consumption (Chapter 3.1.4 and Chapter 8.2), but also expected increased use of heat pumps for medium-temperature process heat. Consumption of renewable energy will increase from 9% of total final energy consumption in production processes to 12% in 2030. This corresponds to an annual rate of increase of 4.3% in renewable energy consumption.

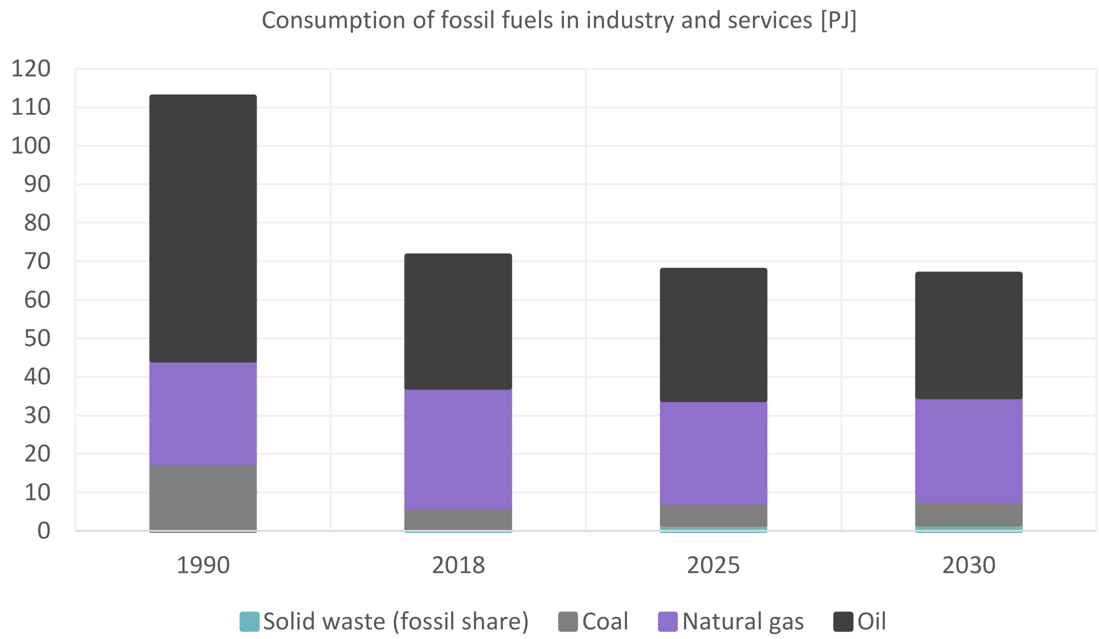


Figure 12: Consumption of fossil fuels 1990-2030 in industry and services [PJ]. Natural gas is the fossil share of mains gas. Oil is classified in the same way as in Danish energy statistics publications, i.e. including petcoke. Energy consumption for space heating in industry and services is included in 1990 figures (footnote 7).

4.2 Trends in Temperature Process Heat

In 2030, about 45% of the consumption of fossil fuels in industry and services is expected to be used for medium-temperature process heat (less than 150 °C). About 25% will be used for high-temperature process heat (more than 150 °C). The remaining 30% will go to internal transport.

Energy consumption for medium-temperature process heat is expected to increase only slightly up to 2030 despite increased activity due to economic growth. Energy-efficiency improvements under the energy saving pool (Ministry of Energy, Utilities and Climate, 2018b) are expected to have an affect up to 2024 in particular.

Figure 14 shows that, today, fossil fuels make up 70% of energy consumption for medium-temperature process heat, and that this share will likely fall to 57% in 2030. About 30% of medium-temperature process heat is supplied as direct firing[13], for example direct drying with gas or for electricity for lighting in greenhouses. Similarly, fossil fuels make up 78% of energy consumption for high-temperature process heat but this share is expected to fall to 72% in 2030. Total energy consumption for high-temperature process heat is expected to increase slightly up to 2030 due to economic growth.

Around 80% of energy consumption for high-temperature process heat is direct firing, especially with coal, coke, petcoke[14] and gas, for example in production of cement and to fire tiles. Here, electrification or thermal alternatives in the form of renewable energy fuels are often not possible with existing technology.

The falling share of fossil fuels is due mostly to an expected increase in the share of renewables in mains gas consumption.

Energy consumption for internal transport is expected to drop slightly over the period despite economic growth, and this is due to increased investment in more energy-efficient vehicles and machinery. A total of 99% of energy consumption for internal transport is expected to be met by fossil fuels in 2030.

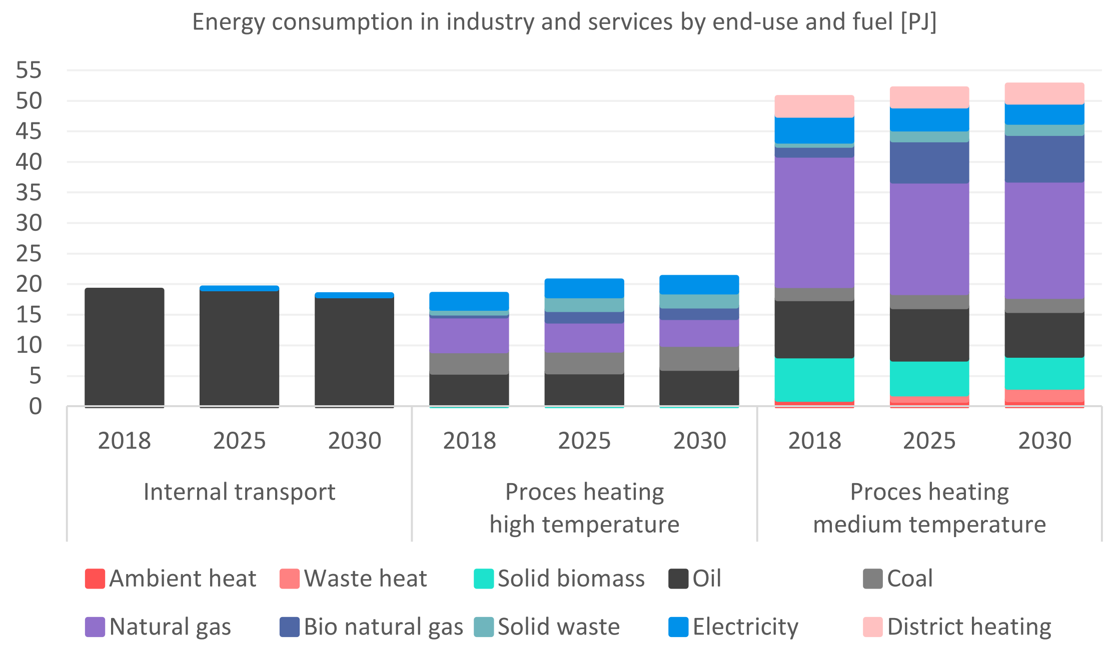


Figure 13: Energy consumption for medium-temperature process heat applications in 2030 [PJ]. This statement differs from the statement of final energy consumption, which does not include surplus heat.

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[13] In direct firing, fuels are fired directly as part of an industrial process. This is in contrast to the use of fuels in boilers, for example, where process heat is generated via steam circulation or hot air.

[14] Contained within the category "oil".

4.3 Heat Pumps for Medium-Temperature Process Heat Will Be in Demand

Figure 14 shows that the use of heat pumps will more than double, with a slight increase in electricity consumption for industrial heat pumps. This reflects expected high efficiencies for industrial heat pumps.

By utilising internal waste heat from industrial processes, heat pumps can supply heat at relatively high temperatures and with high efficiency.

It is expected that industrial heat pumps will supply 4.1 PJ for medium-temperature process heat in 2030.

The projections assume that industries will invest in heat pumps for process heat. Consumption of electricity, ambient heat and waste heat for heat pumps will constitute 8% of energy consumption for medium-temperature process heat in 2030.

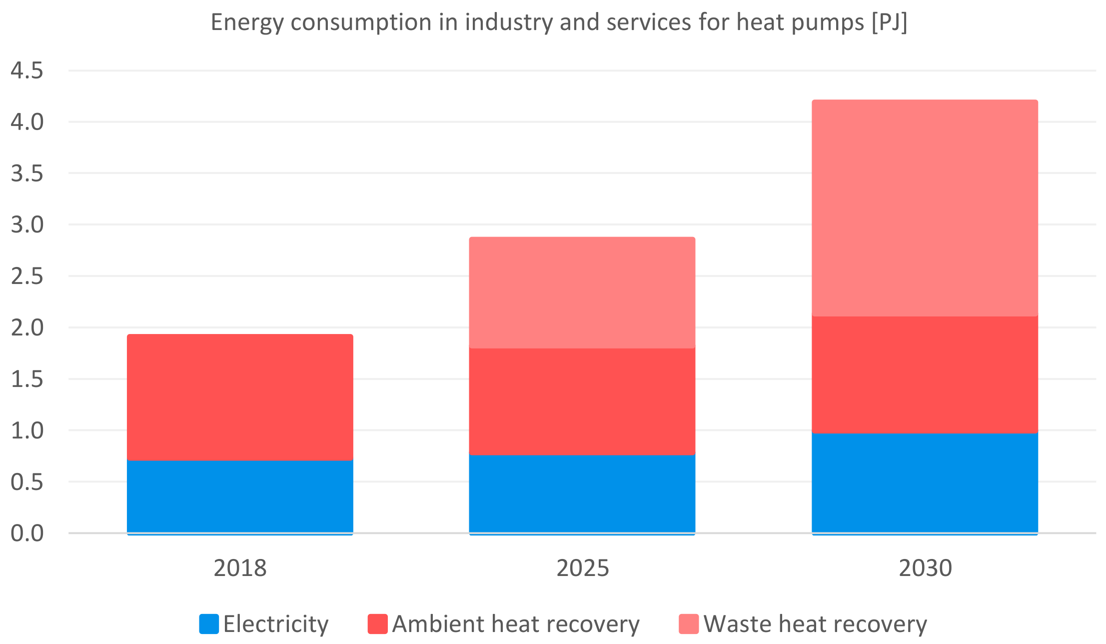

Figure 14: Energy consumption for heat pumps for process heating 2018-2030 [PJ]. "Waste heat recovery" is internal use of waste heat in the form of hot air, steam or hot wastewater.

4.4 CO2 Intensity Further Reduced, But Less So From 2025

The CO2 intensity is a key indicator for CO_2 emissions per economic unit produced. The CO2 intensity will be lower if industry becomes more efficient or replaces fossil fuels with renewables. Structural shifts can also affect CO2 intensity.

Figure 15 shows CO2 intensities by sectors and reveals large differences due to differences in production conditions. For example, the CO2 intensity of construction is 4-5 times lower than that of manufacturing industries.

The overall CO2 intensity will fall by 2.8% annually up to 2025, and then by 1.8% annually up to 2030.

The lower reduction in CO2 intensity after 2025 is mostly due to the expiration in 2024 of the energy saving efforts under the 2018 Energy Agreement (Ministry of Energy, Utilities and Climate, 2018a).

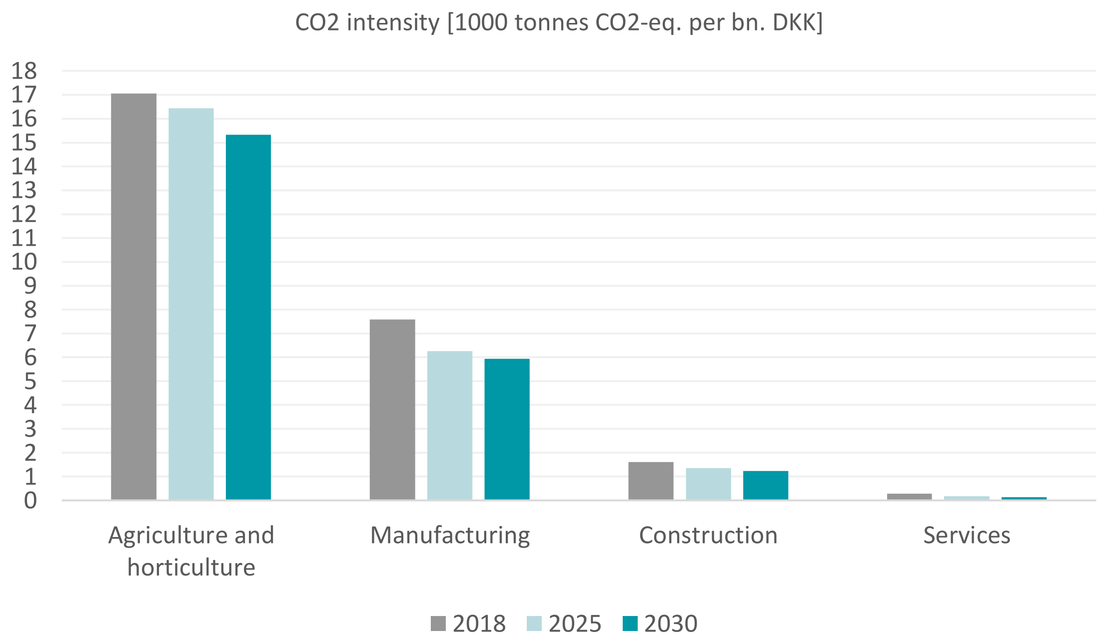

Figure 15: CO2 intensities by sub-sector 2018-2030 ['000 tonnes CO2-eq. per bn. 2020-DKK]. The statement of CO2 intensities includes energy-related emissions from energy consumption for space heating in industry and services, and emissions from industrial processes.

4.5 Industrial Processes - Falling Emissions Overall

Figure 11 shows that emissions from industrial processes have been reduced from 2.3 million tonnes CO2-eq. in 1990 to 2.0 million tonnes CO2-eq. in 2018, and that emissions are expected to fall to 1.8 million tonnes CO2-eq. in 2030.

Emissions from industrial processes stem primarily from cement production and from consumption of fluorinated greenhouse gases (F gases). Previously, there were large emissions of nitrous oxide (N_2O) from production of nitric acid, however this production ceased in 2005. Figure 16 shows that emissions from cement production are on the rise and will make up 75% of emissions in 2030.

Emissions from cement production stem from burning chalk and producing cement at high temperatures (approx. 1,500 degrees Celsius) in large cement kilns. Limestone excavated from the subsurface contains stored carbon in the form calcium carbonate, $CaCO_3$. Burning the limestone in cement kilns therefore releases CO_2, whether the cement is burned using coal or wood pellets, because the CO_2 released is the carbon that was stored in the limestone. The expected emissions from cement production are based on assumptions about economic growth.

F gases are a group of gases used as refrigerants in air-conditioning systems, refrigerators and heat pumps. F gases are also used in industrial products such as fire extinguishers and impregnation agents. Although F gases are used only in limited amounts, they have a significant climate impact. The CO2-equivalent of the F gas SF6, for example, is 22,800, i.e. one tonne of SF6 has a climate impact corresponding to that of 22,800 tonnes of CO_2. The emissions of F gases increased in the 1990s and early 2000s. Emissions peaked in 2009[15] and are expected to fall up to 2030.

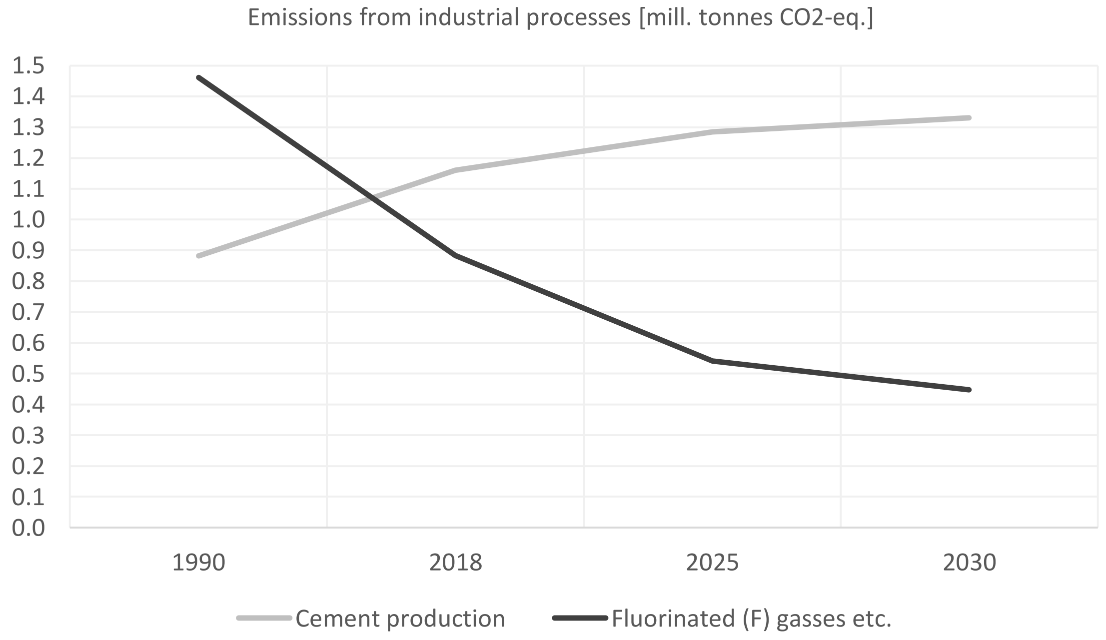

Figure 16: Emissions from industrial processes by source 1990-2030 [mill. tonnes CO2-eq.]

[15] For example, establishing new stationary HFC-based cooling systems was banned from 1 January 2007, however refilling existing systems was still permitted.

4.6 Operational Consumption in the North Sea - Part of the Oil and Gas Industry

North Sea emissions have been calculated together with emissions from the remaining oil and gas industry, which includes refineries. Emissions from the oil and gas industry stem from auto-consumption and flaring, which are calculated on the basis of expected production.

Auto-consumption and flaring in the North Sea are based on natural gas consumption. This natural gas consumption is not included in the mains gas consumption.

There are three elements in projections of North Sea production: existing fields and discoveries; application of new technology; and future, new discoveries.[16] The uncertainty in these projections increases over time, while contributions from new technology and future, new discoveries are subject to considerable uncertainty.

Contributions from existing fields and discoveries are based on the operators' estimates. Contributions from the application of new technology and from future, new discoveries have been projected based on production size and assumptions about expected consumption per unit produced. Technological improvements of existing energy-consuming equipment have not been included.

Projections include redevelopment of the Tyra field[17] and a processing plant being closed down in 2023. The time for the closing down of the processing plant is subject to considerable uncertainty.

Figure 17 shows that production is expected to increase up to 2025 due to new projects. After 2025, production is expected to fall due to ageing fields.

Figure 18 shows that consumption of natural gas from auto-consumption and flaring in the North Sea is expected to fall up to 2025. This is because the Tyra field is expected to be more efficient after redevelopment, with reduced auto-consumption and flaring per unit produced. Furthermore, a processing plant is expected to be closed down. Thus, although production is expected to increase, auto-consumption and flaring are expected to fall. Auto-consumption and flaring are expected to subsequently increase slightly up to 2030, while total consumption is expected to fall. This is because production from the application of new technology and from future, new discoveries is expected to increase, and that contributions from auto-consumption and flaring have been projected based on production size and assumptions about expected consumption per unit produced.

Production from the Norwegian field Trym is processed at the Danish Harald facility and is included in the statement of auto-consumption and flaring. Ravn is a Danish field. However, production from this field is processed on German territory and is therefore included in the Germany statement.

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[16] Projections for oil and gas production and auto-consumption and flaring are based on a forecast published on 27 August 2019 (Danish Energy Agency, 2019f).

[17] The Danish Energy Agency approved the Tyra field redevelopment in October 2017.

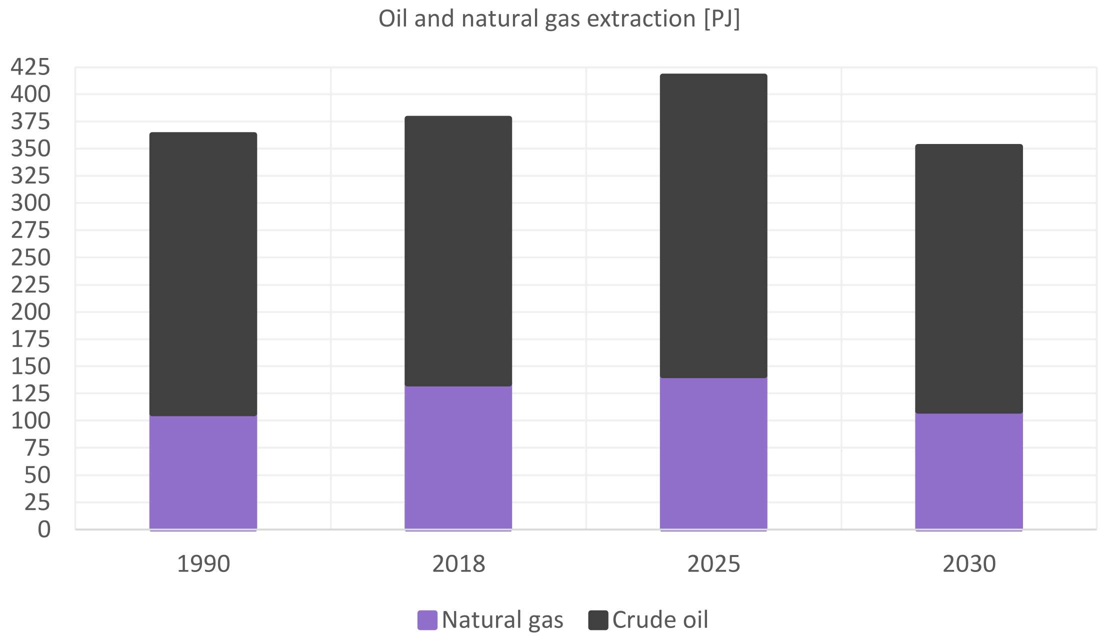


Figure 17: Extraction of oil and natural gas 1990-2030 [PJ].

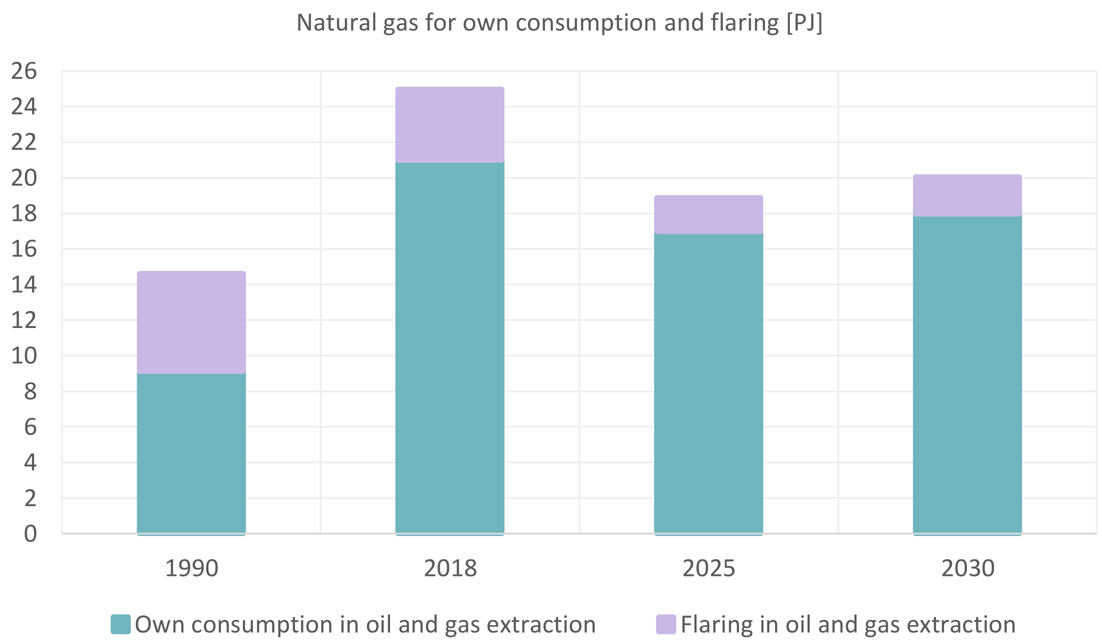


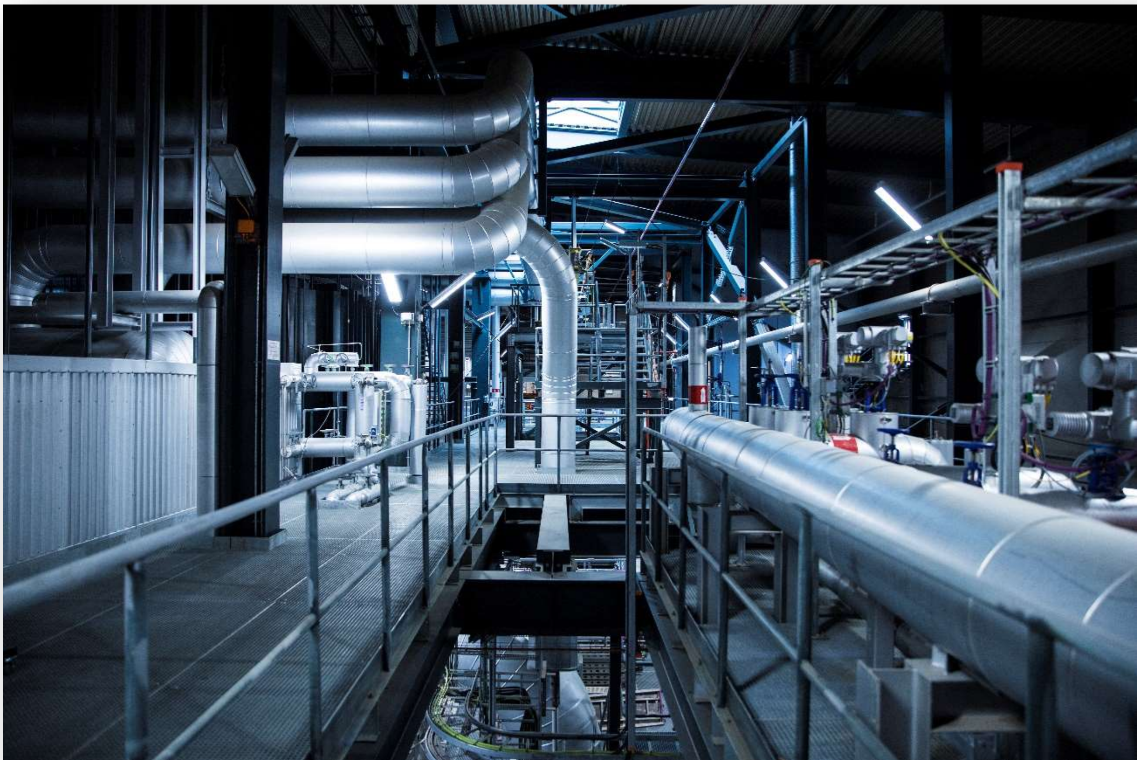
Figure 18: Auto-consumption and flaring in oil and gas extraction [PJ].

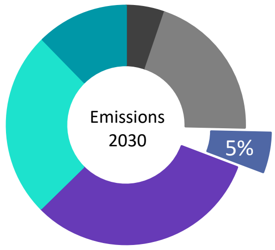
4.7 Sensitivities

The projection of energy consumption in industry and services is sensitive to expectations about economic growth, which has been included as an overall exogenous assumption.

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

In particular, there is uncertainty about how the Covid-19 pandemic will affect the Danish economy and, by extension, emissions from industry and services up to 2030. Previous crisis situations, most recently the financial crisis in 2007-2008, gave rise to considerable changes in emissions levels. Thus, emissions from industry and services fell by 2.9 million tonnes CO2-eq. from 2007 to 2009. The financial crisis is deemed to have left a permanent mark on emissions, driven by structural changes in the industry and services sector towards less CO2-intensive businesses. It is uncertain whether the pandemic will lead to structural changes in industries and services, and it is uncertain in what direction emissions will be affected in the medium and longer term.





5 Waste and Wastewater

The sector is expected to emit 2.3 million tonnes CO2-eq. and will therefore account for 5% of total emissions in 2030.

Figure 19 shows that the sector emitted 2.7 million tonnes CO2-eq. in 2018, corresponding to 5% of total emissions. Waste incineration emits 1.5 million tonnes CO2-eq. and is responsible for 60% of the sector's emissions. Inorganic waste emits CO2 when incinerated, due in particular to its content of plastic, textiles and various mixed products.

The reduction in emissions up to 2030 is due to less organic waste being landfilled[18]. Furthermore it is due to emissions from historical landfills being gradually reduced and due to measures launched to limit methane leaking from biogas plants.

Emissions from waste incineration increased from 0.5 million tonnes CO2-eq. in 1990 to 1.5 million tonnes CO2-eq. in 2018. Emissions from waste incineration are expected to remain at the current level up to 2030 in the absence of any new measures.

Emissions from wastewater treatment are falling overall.

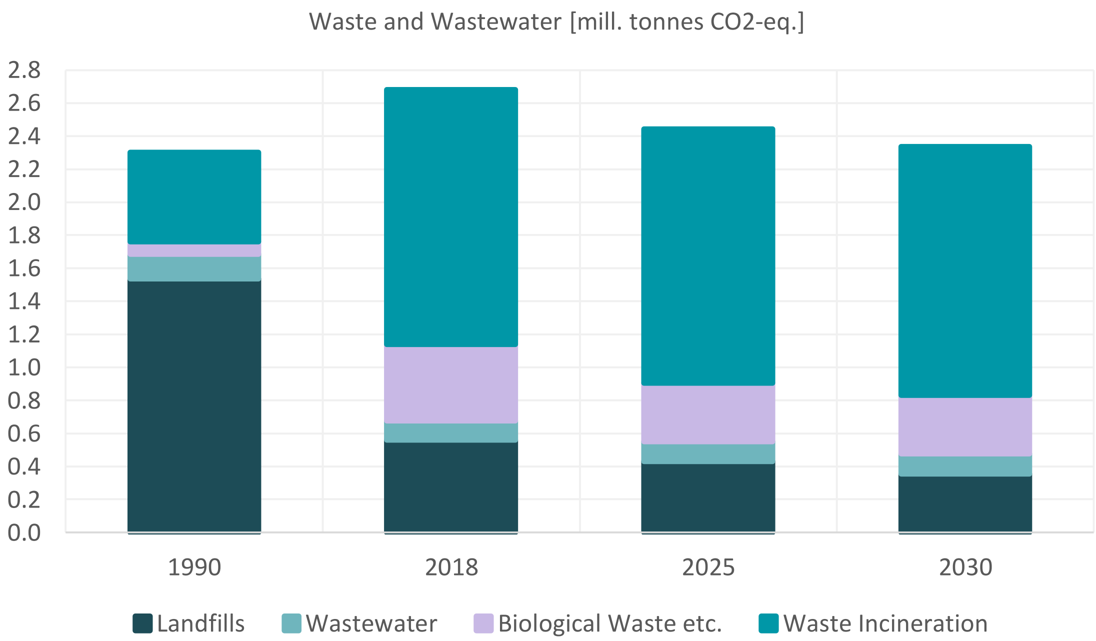


Figure 19: Sector emissions "Waste and wastewater" by main category 1990-2030 [mill. tonnes CO2-eq.].

5.1 Waste Incineration - the Last Large Emitter in District Heating

Figure 20 shows that Danish waste incineration plants are currently incinerating approx. 3.8 tonnes waste, of which 10% is imported waste. Danish waste incineration capacity has increased in accordance with more waste being sent for incineration instead of being

[18] It has been prohibited to landfill waste suitable for incineration since 1997.

landfilled. As well as disposing of the waste, electricity and district heating are produced through waste incineration.

Waste volumes from Danish households and businesses are expected to drop up to 2024 to 3.1 million tonnes. Among other things, this is due to the degree of improved waste separation expected in the absence of any new measures. Expected growth in consumption means that waste volumes will subsequently increase up to 3.2 million tonnes in 2030. Imported waste volumes are expected to decrease up to 2030, while at the same time waste incineration capacity is expected to drop as a number of older and defunct kiln lines are taken out of service.

5.2 Landfills, Biological Waste Treatment and Wastewater

Figure 21 shows that the most important source of other emissions in 2030 is methane, stemming primarily from landfills and leaks from biogas plants. Methane and nitrous oxide emissions from composting and wastewater treatment are also included. Finally, smaller emissions from fires and crematoria are included.

Emissions of methane from landfills are still falling, and this is due to relatively less waste being landfilled. However, volumes of organic degradable waste are increasing. The 1997 ban on landfilling waste suitable for incineration caused a drop in volumes of landfilled organic waste from 0.8 million tonnes in 1996 to 0.1 million tonnes in 2009. At the same time, in 2016, a subsidy scheme was established (Executive Order no. 752 of 21 June 2016) for the establishment of bio-covers at landfills and waste disposal sites. However, pending documentation for the effect of such bio-covers, any such effect has not been included in DCEO20. It has been estimated that bio-covers can reduce emissions from waste disposal sites and landfills by 0.1-0.2 million tonnes annually. However, the basis for this estimate has yet to be verified.

Emissions from biogas plants and composting followed an upward trend up to 2018. The projections assume that the initiative launched to prevent leaks at biogas plants will lead to a reduction in the emissions factor from 2020, from an historical emissions factor of 4.2% to only 1%.[19] This will contribute to emissions from biological waste treatment being reduced by 0.1 million tonnes CO2-eq. up to 2030.

Emissions from wastewater treatment are increasing overall, which can be attributed to a fall in emissions of nitrous oxide and an increase in emissions of methane. In 2018, a subsidy scheme was launched under the Danish Environmental Protection Agency's Environmental Technology Development and Demonstration Programme (MUDP) programme. This subsidy scheme is expected to lead to better reporting of nitrous oxide emissions from wastewater treatment plants and to reduced emissions.

[19] The assumed lower emissions factor will be verified through measurements, and, as with other areas in connection with deviations, this could require adjusting future statements.

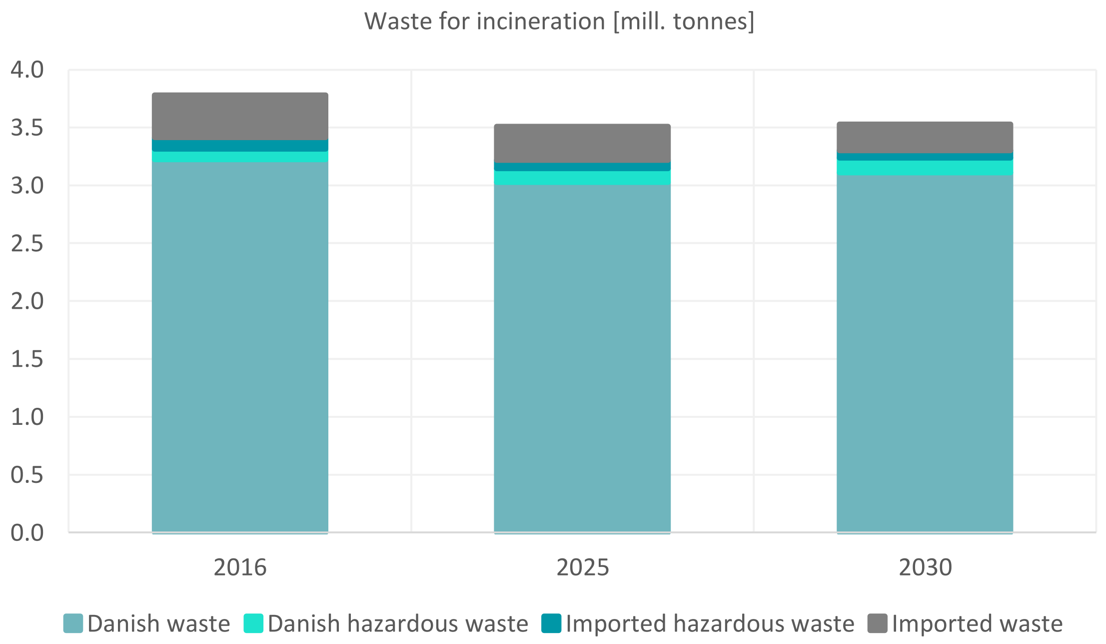


Figure 20: Waste volumes for incineration 2016-2030 [mill. tonnes]. Note that the statistical year here is 2016, because, as of May 2020, there was no detailed statement for 2018 of incinerated waste volumes.

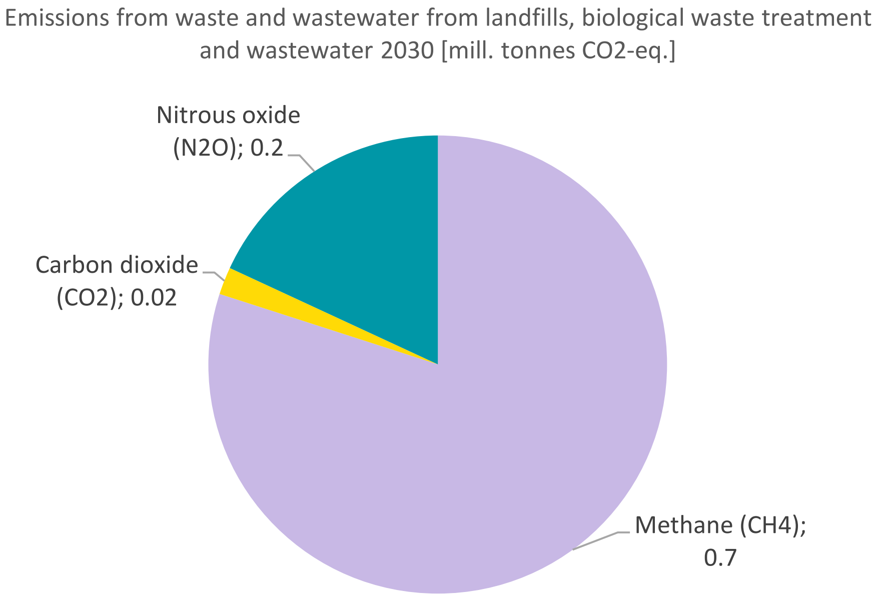


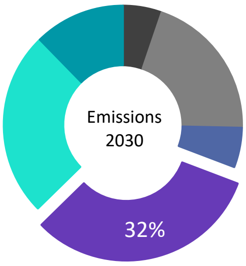
Figure 21: Emissions 2030 by greenhouse gases - methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) for landfills, biological waste treatment and wastewater [mill. tonnes CO_2-eq.].

5.3 Sensitivities

The projection of imported waste volumes has been calculated on the assumption of expected continued demand for Danish waste incineration capacity up to 2030. This assumption is sensitive to developments in the market for combustible waste.

Emissions from waste incineration are sensitive to the waste mix, including its relative shares of fossil and organic fractions. The waste mix is assumed to remain the same throughout the projection period. Determination of the waste mix today is associated with some uncertainty, and this uncertainty will become more pronounced up to 2030.

Finally, there is uncertainty linked to the effect of bio-covers not yet included in the calculations, and to the expected reduction in methane leaks from biogas plants.



6 Transport

The sector is expected to emit 13.7 million tonnes CO2-eq. and will therefore account for 32% of total emissions in 2030.

Transport includes road transport, rail transport, domestic sea transport, domestic air transport and defence. International air transport and international sea transport are not included in the UN emissions statement. The emissions and energy consumption of corporate vehicles used in production are included in Chapter 4 under "internal transport".

Figure 22 shows that emissions from transport have increased from 12.0 million tonnes CO2-eq. in 1990 to 13.9 million tonnes CO2-eq. in 2018, corresponding to 25% of total emissions that year. Emissions are expected to increase slightly up to 2025 and then fall slightly up to 2030.

Road transport is expected to account for 92% of transport emissions in 2030. Passenger cars alone will account for 58% of emissions by road transport in 2030, while transport of goods (vans and lorries) will account for 37%.

The increase in emissions up to 2025 depends on a growing transport volume and extensive use of fossil fuels.

The drop in emissions after 2025 is due primarily to increased electrification of road and rail transport, as well as increased efficiency of vehicles. Electrification of rail transport will speed up after 2027, in particular, with the expected completion of electrification of the Fredericia-Aalborg and Roskilde-Kalundborg rail links and commissioning of new equipment. Emissions from rail transport are therefore expected to drop by 71% between 2018 and 2030.

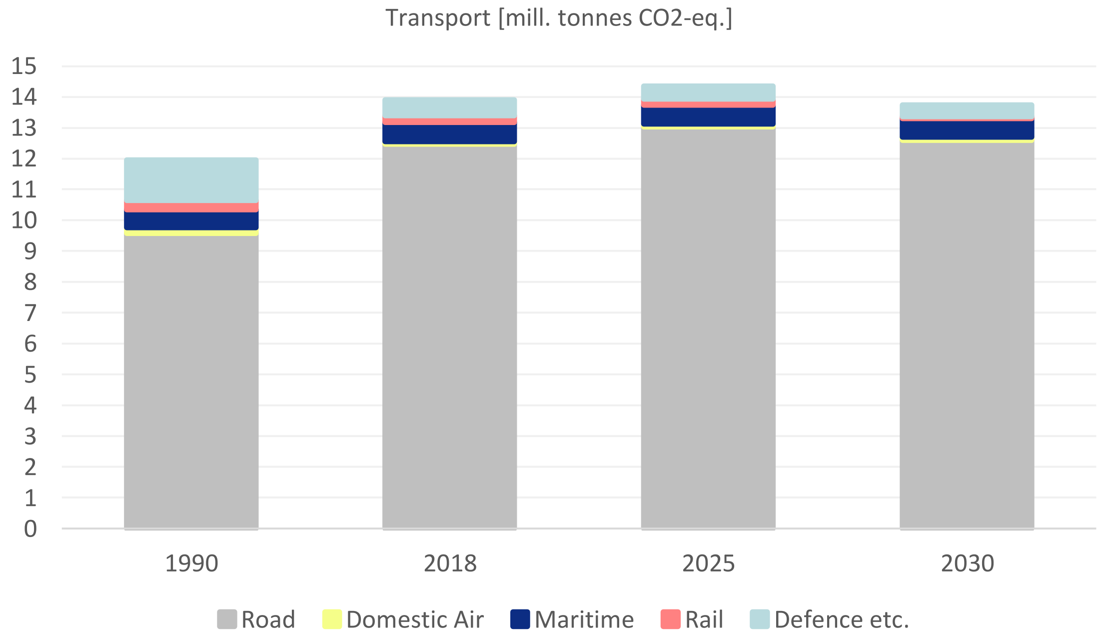


Figure 22: Sector emissions "Transport" by type 1990-2030 [mill. tonnes CO2-eq.].

6.1 Increased Road Transport Demand - Oil Consumption Declines After 2025

The demand for road transport is expected to increase by almost 24% from 2018 to 2030.

Figure 23 shows that fossil energy consumption by transport totalled 183 PJ in 2018, that it will increase to 190 PJ in 2025, and that consumption is then expected to fall. In 2030, consumption of fossil fuels in transport will be approximate to consumption in 2018.

Energy consumption by lorries reflects the new EU emission performance standards, which are expected to enhance the efficiency of vehicles and reduce diesel fuel consumption. The average service life of lorries is around 8 years, and the new EU emissions standards will therefore have an impact in the projection period. Zero-emission or low-emission lorries are not expected to be widely available or cost-effective up to 2030 in the absence of any new measures.

The effect of energy-efficiency improvements on passenger cars and vans will have less impact on fossil fuel consumption during the projection period, as the average service life of these vehicles is around 15 years. It is expected that car manufacturers will meet the EU emission performance standards mostly by developing and manufacturing zero-emission and low-emissions standard vehicles (such as electric cars). Therefore, petrol and diesel cars will become more energy-efficient only to a limited extend up to 2030.

Furthermore, electrification of railroads will contribute to reducing fossil energy consumption.

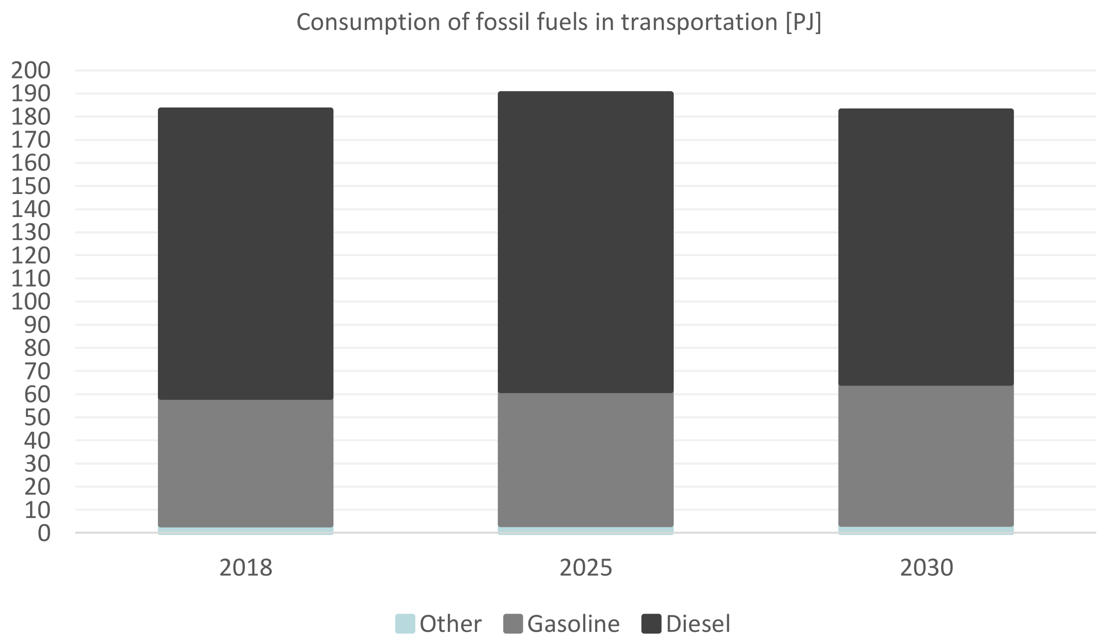


Figure 23: Consumption of fossil fuels for transport [PJ]

6.2 Electrification of Road Transport Causes Fall in Emissions after 2025

Electric and plug-in hybrid cars are expected to account for 36% of total sales of passenger cars in 2030, corresponding to 100,000 passenger cars, and 380,000 cars out of an expected total stock of 3.35 million passenger cars in the same year, i.e. 11%.

Sales of electric and plug-in hybrid cars will increase, particularly after 2025, due to expected technological developments and lower prices, as well as an expected increase in both supply and demand. This trend is not least driven by the EU Regulation, which sets out performance standards for average emissions from passenger cars sold in 2021, 2025 and 2030 (European Commission, 2019). It is expected that car manufacturers will mostly meet the new standards by offering and selling proportionally more electric cars.

The replacement with new passenger cars will happen gradually, for example due to the expected long average service life of passenger cars, which is around 15 years.

Vans and buses are also expected to contribute to increased electrification after 2025.

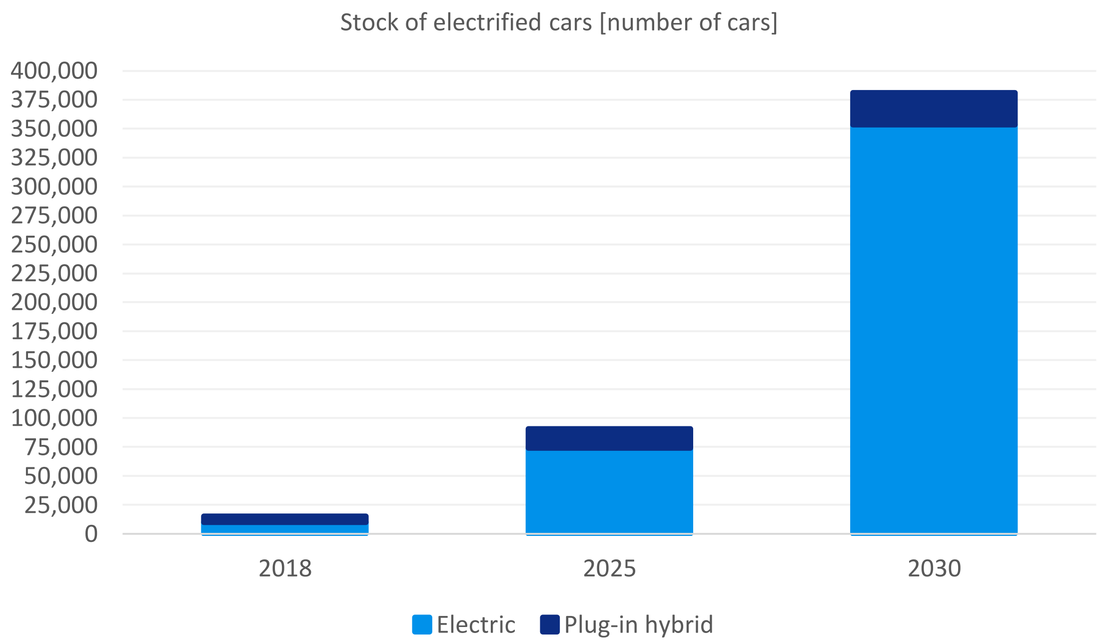


Figure 24: Electric passenger cars - number and share of stock 2018-2030 [numbers].

6.3 Consumption of Electricity and Renewables Increases

Figure 25 shows that consumption of electricity and renewable energy for transport will increase in particular after 2025.

Consumption of renewable energy for transport has previously been dominated by the consumption of biofuels. Electricity produced from renewable energy will increasingly contribute to the consumption of renewable energy for transport.

In 2020, the requirement for higher biofuel blends in petrol and diesel for land transport will increase from 5.75% to 7.6%. The biofuel blending requirement will ensure that Denmark meets the EU requirement for 10% renewables in the transport sector in 2020. The requirements for higher biofuel blends in 2020 will be met using the E10 petrol standard (10% bioethanol in petrol) and the B7 diesel standard (7% biodiesel in diesel). After 2020, the requirement will be reduced again to 5.75%. The E10 standard is expected to be maintained, while the B7 standard is expected to be reduced significantly. Ultimately, however, it is up to the fuel suppliers, as long as they meet the biofuel blending requirement.

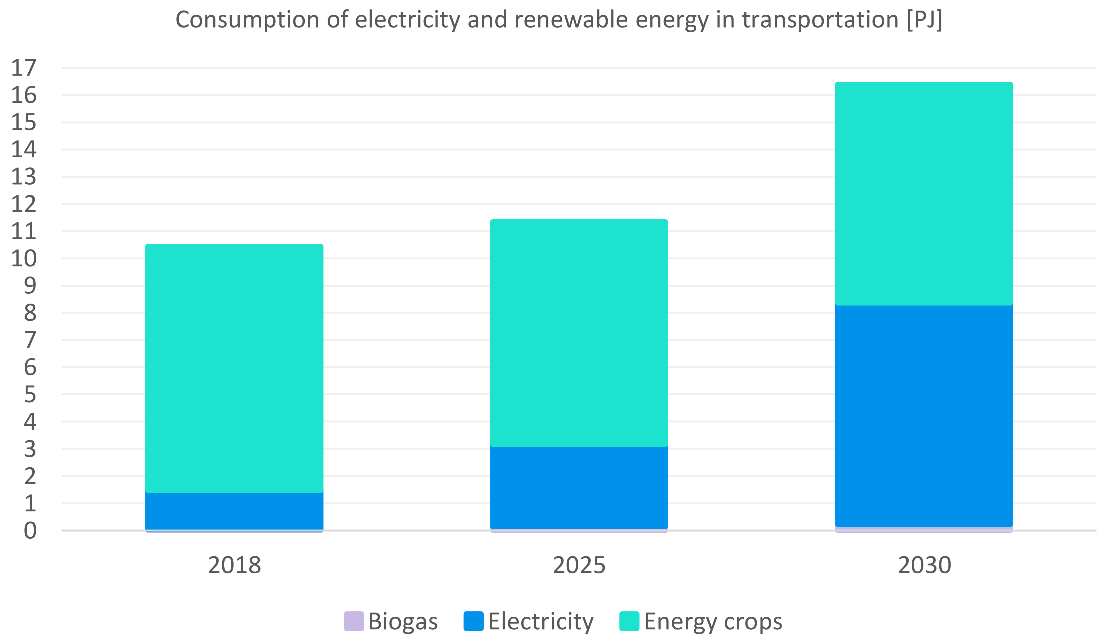


Figure 25: Consumption of electricity and renewable energy for transport 2018-2030 [PJ].

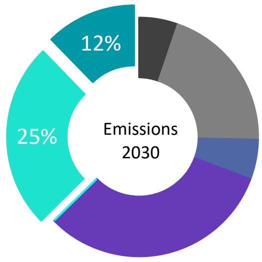
6.4 Sensitivities

The projection of emissions from the transport sector is particularly sensitive to growth in transport demand in road transport and in the breakdown of sales of passenger cars between fuels.

DCEO20 uses growth rates from the National Transport Model (LTM), which indicates the annual growth in road transport demand by vehicle type (Passenger cars, Vans, Lorries and Buses). For passenger cars, this means an increased demand for transportation of 27% from 2018 to 2030, corresponding to an annual increase of around 2%. A change of ± 50% in the growth rate of transportation by passenger car will result in a change of -0.7 million tonnes CO2-eq in emissions from passenger cars in 2030 if growth rates fall, whereas an increase will give rise to an additional 0.8 million tonnes CO2-eq.

Emissions also depend on expectations about the share of electric and plug-in hybrid cars. Expected sales of electric passenger cars depend on various factors such as price, technological developments and infrastructure. In addition, there may be a number of barriers to electric vehicles becoming more widespread, for example the possibility of substitution (the supply), market penetration (diffusion), technology uncertainty, charging rate, individual preferences in appearance/model/brand, as well as climate and environmental impacts.

In order to reflect the uncertainty in sales of electric cars, a sensitivity analysis was conducted, showing that price developments for electric cars varied by ±50% in relation to the central estimate. Moreover, the sensitivity analysis includes assumptions about faster and slower reduction of the barriers that restrict sales of electric vehicles in relation to the central estimate. The sensitivity analysis results in an upper assessment of the share of new car sales of 65% in 2030, and a total number of cars of 750,000 cars in 2030, resulting in a reduction in emissions from passenger cars of 0.8 million tonnes CO2-eq. in relation to the central estimate. Similarly, a lower assessment of the share of sales resulted in 18% in 2030 and a total number of cars of 190,000 cars, resulting in an increase in emissions from passenger cars of 0.4 million tonnes CO2-eq. in relation to the central estimate.



7 Agriculture, Forestry and Other Land Use

Agriculture, forestry[20] and other land use are projected to emit 16.1 million tonnes CO2-eq. in total and will therefore account for 37.4% of total emissions in 2030.[21]

Agriculture and forestry and other management of land, particularly in agriculture, play an important role in climate impacts. This impact is roughly divided into two categories. The first category includes agricultural production in livestock housing systems and on cropland causing emissions of the greenhouse gases methane (CH4) from animal digestion and from fertiliser management, as well as nitrous oxide (N2O) from nitrogenous livestock manure, chemical fertiliser and crop residues. The other category includes the role of forests and other land (primarily agricultural cropland and grassland) as carbon stocks. CO2 is either stored in or released from trees, plants and soils in this category, depending on how the soils and forests are managed. The most important assumptions behind the calculation of emissions from agriculture, forestry and other land use are shown in Appendix 4.

Figure 26 shows that agricultural emissions have fallen from 13.2 million tonnes CO2-eq. in 1990 to 11 million tonnes CO2-eq. in 2018, corresponding to a reduction of 16%. Emissions from agriculture up to 2030 are expected to remain more or less unchanged.

In 1990, forests had a net carbon removal corresponding to 0.5 million tonnes CO2-eq. Up to 2030, forests are expected to have annual net emissions of 0.2 million tonnes CO2-eq. This means that the total amount of carbon stored in Danish forests (excluding the carbon stored in wood products) is expected to fall slightly up to 2030. This is somewhat offset by a corresponding increase of carbon stored in wood products. The consequent total net emissions from carbon stored in forests and wood products is expected to be 0.1 million tonnes CO2-eq. in 2030.

Net emissions from other types of land use (in addition to forestry) are expected to fall from 7.0 million tonnes CO2-eq. in 1990 to 5.2 million tonnes CO2-eq. in 2030. Most of these emissions come from agricultural cropland and grassland.

There can be large annual fluctuations in the calculation of the net carbon emissions or uptake of forests and other land. There is also great uncertainty associated with projecting the expected annual changes which are affected by the weather in the individual years, among other factors. Finally, future logging in forests and specific emissions per hectare from agricultural organic soils is uncertain.

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[20] Forests comprise carbon pools in living trees, in deadwood and in litter (such as leaves) on the forest floor, carbon pools in forest soils, for example in the form of roots, and carbon stored in wood products.

[21] Energy-related emissions from agriculture and land management are described in Chapter 4.

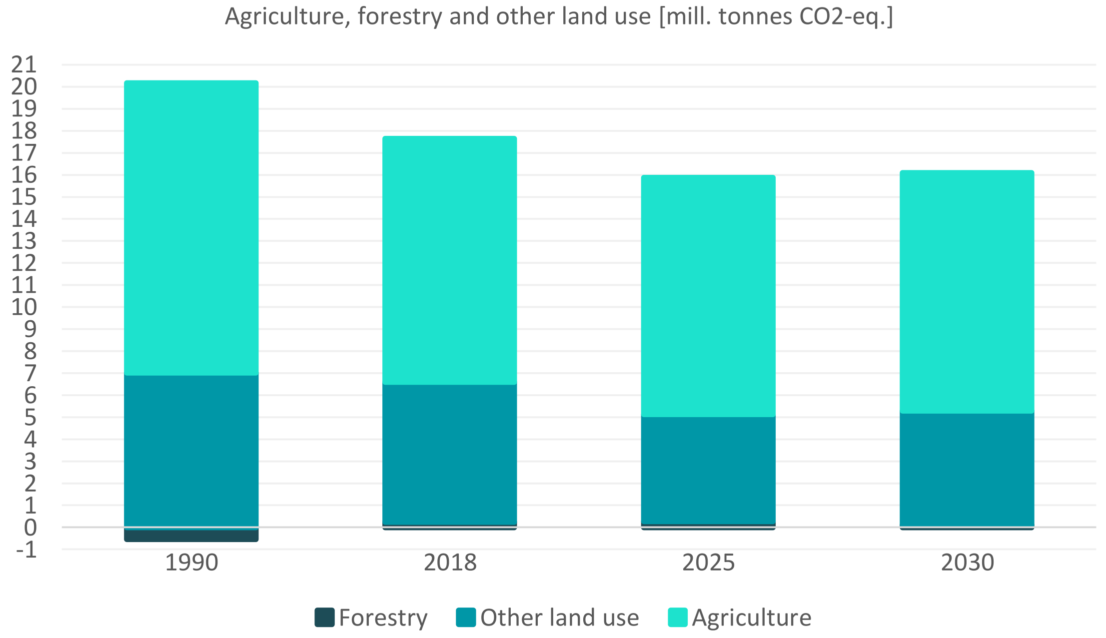

Figure 26: Sector emissions "Agriculture, forestry and other land use" by main categories 1990-2030 [mill. tonnes CO2-eq.]. Emissions from other land use (emissions primarily from the carbon stored in agricultural soils) are indicated as an average of the model results for the years 2024-26 in 2025, and of the years 2029-31 for 2030. In observed years, there will be large natural fluctuations in emissions.

7.1 Emissions From Agriculture Will Be Stable up to 2030

Agricultural production in livestock housing systems and on cropland involves a number of complex biological and chemical processes, resulting in emissions of methane and nitrous oxide.

Figure 27 shows that emissions from decomposition of fertiliser on fields have been reduced from 5.7 million tonnes CO2-eq. in 1990 to 4.1 million tonnes CO2-eq. in 2018. This reduction is due to a 50% reduction in the use of chemical fertiliser, a number of environmental measures that have reduced nitrogen leaching, and developments in housing systems, fertiliser management and environmental technology. The primary reduction in emissions took place from 1990 to 2002, and thereafter emissions from fertiliser on fields remained at approximately the same level. Emissions from animal digestion will remain relatively stable despite the fact that the number of animals is projected to increase up to 2030. Emissions from the increasing number of animals are offset in part by a drop in emissions from livestock manure up to 2030, which, among other things, is due to greater use of environmental technology such as biogasification of slurry, slurry acidification and slurry cooling.

In the absence of any new measures, total emissions from agriculture are expected to remain at the current level up to 2030, when emissions are projected to be 10.8 million tonnes CO2-eq.

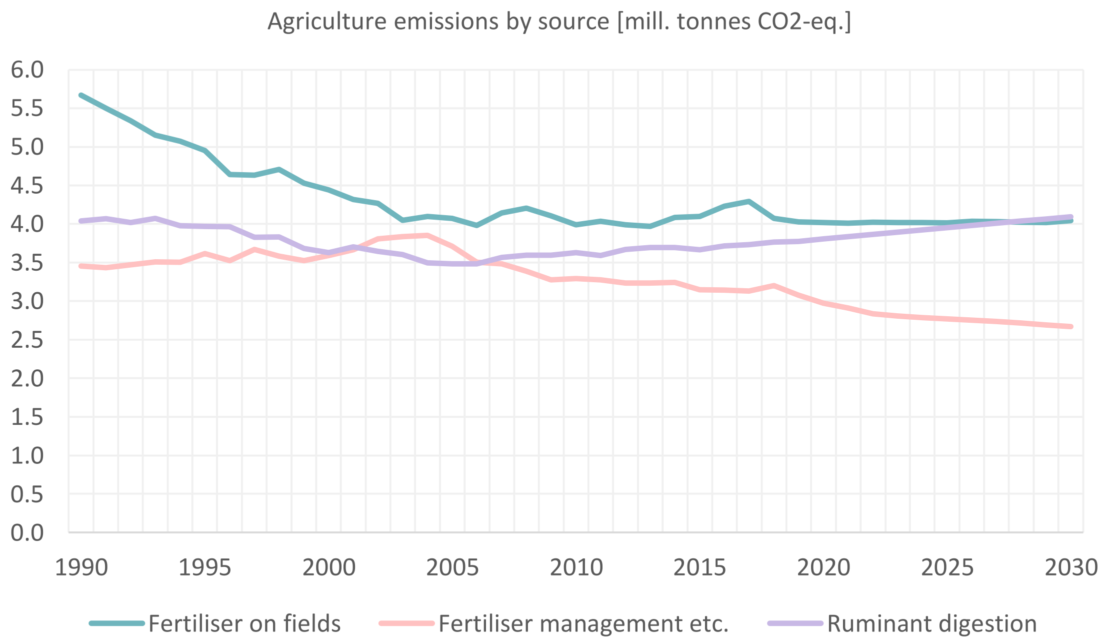

Figure 27: Emissions from agriculture by the categories ruminant digestion, fertiliser management and fertiliser on fields

Text box 3: Principal sources of emissions from agriculture.

Livestock digestion: The digestion of feed in a cow's rumen produces methane. The composition and size of the livestock population affect the level of emissions, as the level of emissions of methane from ruminant digestion (especially in dairy cows) is quantitatively higher than emissions from monogastric production animals such as pigs. Emissions from ruminant digestion can be impacted through feeding practices and breeding.

Fertiliser management: Methane and nitrous oxide are produced when manure is stored in livestock housing systems and in slurry tanks. The volume and type of manure (slurry, solid manure or deep litter) affect emissions, and so does the way in which the slurry is managed and stored in the housing systems and slurry tanks. Storage duration, temperature and technology for treating manure, for example in-house slurry acidification and possibly sales to biogas plants, are crucial factors.

Decomposition of manure on agricultural soils: When nitrogen in manure is converted on soils, nitrous oxide is produced. The level of emissions is determined by the amount of manure, the time manure is spread on fields and the type of manure.

7.2 The Carbon Pool in Forests and Other Land Changes From Year to Year

Forests and other land play an important role as carbon pools, i.e. the amount of carbon stored in living and dead biomass above and below ground and in soils. Carbon from atmospheric CO_2 is absorbed by plants and released by decay and combustion of biomass. Similarly, carbon from atmospheric CO_2 is both stored in and released from soils in forests, for example, and in agricultural cropland and grassland.

Literature linked to the national climate accounts uses the term LULUCF (Land-Use, Land-Use-Change & Forestry). The LULUCF sector is divided into six subsectors representing carbon pools in forests, cropland, grassland, wetlands, settlements and other land, respectively. When countries report internationally on yearly changes in carbon pools in forest land and other land, they calculate the annual changes in the form of emissions or removals in each sector.

Fejl! Henvisningskilde ikke fundet. shows that there may be large annual fluctuations in emissions from and removals to the carbon pools in the sectors. Moreover, there is great uncertainty associated with projecting the expected annual changes which is affected by the weather in the individual years and forest felling rates, among other factors.

For example, the figure shows that the forest carbon pool has been in balance for many years with the exception of the period 2006-2015, when large removals (that is uptake of CO2 in the forest carbon pool) were observed. The other sectors dominated by agricultural soils in cropland and grassland generate emissions, and this is primarily due to drainage and cultivation of agricultural soils with a high organic matter content.

Emissions in the projected years vary considerably, see **Fejl! Henvisningskilde ikke fundet.**. This is because model calculations using forecasts made by the Danish Meteorological Institute, for example, use a series of specific model assumptions on weather (temperature), and this results in varying emissions from agricultural soils. As illustrated above in Figure 26, the calculation in Denmark's Climate and Energy Outlook calculates emissions from forests and other land in all years as approximated normal years based on a three-year average of model-based calculations of emissions.

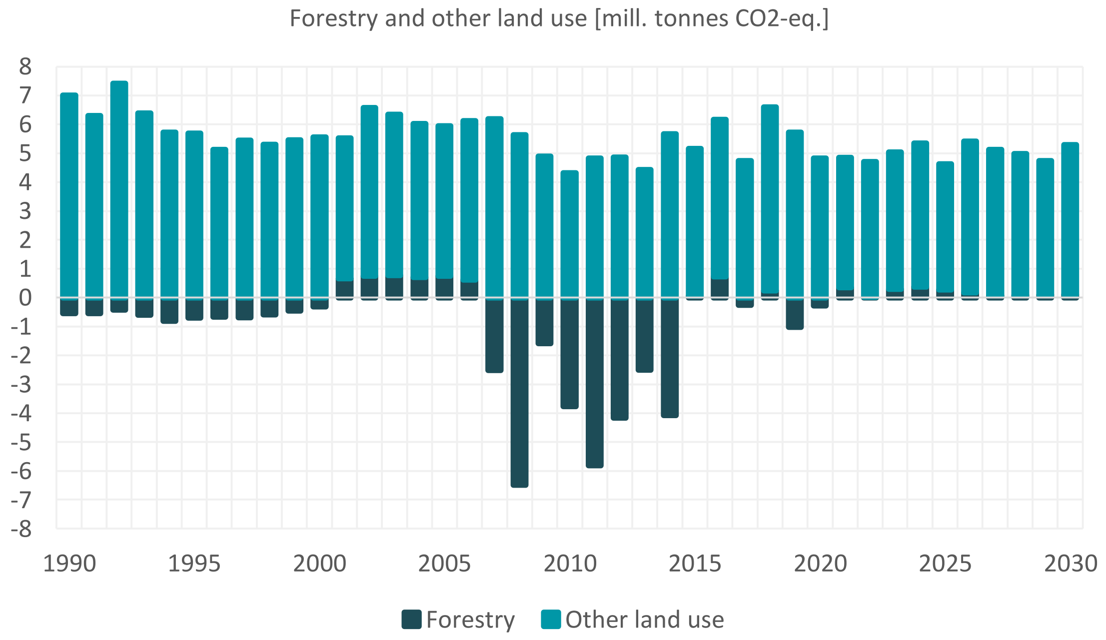

Figure 28: Emissions and removals in forests and other land 1990-2030 [mill. tonnes CO2-eq.]. Positive numbers are emissions, negative numbers are removals.

7.3 The Area of Forests Has Grown and Accounts for an Essential Carbon Pool

Since 1990, Denmark's forests have grown in size and in density (volume of wood per hectare). From 1990 to 2018, forest growth has caused total net removals of 33 million tonnes CO2 from the atmosphere, and this is now being stored in the carbon pool of forests.[22] The total carbon pool of forests has been estimated to be around 46 million tonnes of carbon (C), corresponding to 170 million tonnes of CO2 in living biomass below and above ground and in deadwood above ground.[23]

Up to 2030, a slight annual net emission from forests (including emissions from forest soil) of 0.2 million tonnes CO2-eq. is expected. However, an increase in the carbon stored in wood products corresponding to 0.15 million tonnes CO_2 annually is also expected, which means that the total carbon balance of forests and wood products is close to zero. After 2035, the carbon pool of forests is expected to grow again.

[22] Moreover, it has been estimated that a fairly constant level of carbon has been stored in wood products since 1990, as there has been a slight net emission from the pool of around 0.4 million tonnes of CO2 since 1990.

[23] This statement of the total accumulated carbon pool of forests does not include carbon stored in forest soils.

Text box 4: Removals and emissions in forests.

> Forests comprise carbon pools in living trees, in deadwood and in litter (such as leaves) on the forest floor, carbon pools in forest soils, for example in the form of roots, as well as the carbon stored in wood products.
>
> Atmospheric CO_2 is removed when trees grow, and the photosynthesis process releases oxygen and stores carbon in the biomass of the trees. Carbon is released again as CO_2 to the atmosphere when the tree decays or is burnt.
>
> Some of the biomass from felled trees is used for energy purposes, which means carbon is released as CO_2. These emissions are not calculated as energy-related emissions, but for Danish biomass they are included in the statement of emissions from forests as a reduction of, or reduced growth in, the carbon pool of forests. Some of the biomass from felled trees is used for wood products, which will continue to store some of the carbon. The calculation of emissions from forests includes a carbon pool in the form of harvested wood products (sawn wood, plates and paper) until such wood products have decayed or been burnt.

This means that the carbon pool in trees, brushwood, roots, leaves, deadwood and soil increases when the trees of the forests grow. The carbon pool in the forest is reduced when trees die and decay, or are cut and burned. The carbon pool in wood products is affected by the use of biomass from forests.

Whether forests provide a yearly net removal or a net emission depends on the relationship between the annual growth and the annual logging/decay of trees. The growth varies according to soil, tree species and climate. Logging varies according to stand structure (i.e. the distribution of trees by species and size within a stand) as well as market trends for wood and wood products.

The statement in DCEO20 of removals by and emissions from forests is based on Denmark's national forest reference plan from December 2019 (Johannsen et al., 2019). This reference plan was drawn up for reporting under the EU LULUCF Regulation, using models developed on the basis of studies on the development of forests from 2000-2009.[24]

Overall, the carbon pool in forests (excluding the pool in wood products) is expected to fall slightly up to 2030 and further towards 2035. For example, this is because relatively old and carbon-containing trees will be felled, and this removes more carbon from forests than is expected to be absorbed by the remaining trees as well as by new trees in existing and new forests.

The calculation of the expected developments in the total carbon pool of forests includes increased removals from 1,900 hectares of afforestation annually in the period up to

[24] The projections carried out by the Department of Geosciences and Natural Resource Management and by the Danish Centre for Environment and Energy have subsequently been transferred to the reporting to the UNFCCC and included with the other LULUCF inventories. The figures used are shown in Table 2, p. 39-40 in: Johannsen et al, December 2019

2050. Expected afforestation is based on the assumption that funding for existing subsidy schemes will be continued, including state afforestation of 300 hectares annually, private afforestation under the rural development programme of 1,000 hectares annually and 600 hectares annually from other afforestation. Removals from new afforestation will only be relevant in the long term, as growth for many tree species will not be significant until after 10-20 years.[25]

7.4 Emissions From Other Land Areas Stem from Drainage and Soil Treatment

As described for forests, plants remove CO_2 from the atmosphere, and the photosynthesis process releases oxygen and binds organic carbon compounds. When plant residues, roots and other organic material are left in the soil, they contribute to increased carbon storage in these soils. For agricultural areas, the organic carbon in the soil is decomposed in connection with soil preparation and drainage that oxidize the soils and speeds up the decomposition of organic matter into CO_2.

Fejl! Henvisningskilde ikke fundet. shows that other land areas have emitted 5.5 million tonnes CO2-eq. annually on average since 1990. These emissions are expected to decrease to 4.9 million tonnes CO2-eq. in 2025[26] and 5.2 million tonnes CO2-eq. in 2030.[27] The reduction in 2030 compared with emissions today will be a consequence of increased yields, the establishment of catch crops, the absence of organic matter on some soils previously categorised as organic soils, and the re-establishment of wetlands on organic agricultural soils.

Most agricultural areas consist of mineral soils, where 300 million tonnes of carbon are estimated to be stored, corresponding to 1,100 million tonnes of CO_2. The majority of this carbon is very persistent. According to an assessment by the Danish Centre for Environment and Energy (DCE), the carbon pool in these soils is expected to increase slightly up to 2030, and an average of 0.4 million tonnes CO2-eq. is expected to be stored annually. Emissions and removals in mineral soils depend on a balance between returning plant residues and roots, the frequency of soil preparation and climatic conditions.

The majority of net emissions from other land use categories stem from carbon-rich organic agricultural soils. The Danish Centre for Environment and Energy has included emissions from these lands of 4.8 million tonnes CO2-eq. in 2018 and 4.4 million tonnes CO2-eq. in 2030. The carbon pool in organic soils, which make up 6.8% of the total area of agricultural land, is expected to be reduced up to 2030. The emissions from organic soils will be due to a continued carbon loss as long as the soils are drained/farmed. This

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[25] The carbon content in vegetation on fields is moreover deducted in connection with conversion of agricultural land to forest, according to the UN Climate Convention accounting rules, and so it will be some time before the carbon removal by the newly planted forest exceeds the emissions deducted, which is why new afforestation will initially appear as net emissions in the emission inventory.

[26] Average of the years 2024-26.

[27] Average of the years 2029-31.

carbon loss will continue until all organic material has been decomposed or the lands have been re-established as wetlands.

The calculation includes expected removal of organic agricultural areas from agricultural activities and conversion to wetlands.[28] Conversion of these areas is enabled through support schemes included in the Finance Act agreement for 2020 which allocates DKK 2 billion for land conversion in the period 2020-2029.[29] There is uncertainty regarding the specific effect of this land conversion, for example regarding the specific emissions factors for the agricultural soils that are taken out of cultivation, see 7.5.

7.5 Sensitivities

Developments in the number of agricultural livestock have a significant impact on emissions from the agricultural sector. In 2030, 15% more or fewer dairy cattle will increase or reduce annual emissions from agriculture by at least 0.5 million tonnes CO2-eq. respectively (The Danish Energy Agency, 2019d).

There is uncertainty about future growth and logging in forests. **Fejl! Henvisningskilde ikke fundet.** shows that emissions from forests have varied from net removals of 6.5 million tonnes CO2-eq. to net emissions of 0.9 million tonnes CO2-eq. The outlook expects forests to have net emissions up to 2030 because a major part of the carbon pool of forests is stored in trees that have reached an age at which they are expected to be felled. Experience shows that it is difficult to project the developments in the carbon pool of forests.

DCEO20 is not based on a separate analysis of the expected growth, logging or stock changes in Danish forests up to 2030 and onwards. Instead, the report uses the projections that form the basis for Denmark's national forest reference plan from December 2019 (Johannsen et al., 2019). These projections were carried out for a slightly different purpose and with models that were developed on the basis of studies on the development of forests from 2000-2009 and for reporting under the EU LULUCF Regulation. This projection is currently considered to be the best starting point for assessing the future development of forests. However, it will be considered whether a new forest projection is necessary, taking into account forest management practices in the period since 2009, afforestation, etc.

Fejl! Henvisningskilde ikke fundet. shows that emissions from other land areas, primarily agricultural areas, are sensitive to weather conditions. Over the past ten years, emissions have fluctuated between 4.3 and 6.4 million tonnes CO2-eq. Future emissions depend on the future weather situation. The calculations for DCEO20 use a series of weather data with random variations in individual years. This means, for example, that

[28] The area has been calculated as the total area of agricultural land with organic soils. Establishment of wetlands typically involves both natural areas and mineral soils within the boundaries of the area. On the basis of established projects to reduce nitrate and projects under the organogenic soils scheme, the Danish Centre for Environment and Energy (DCE) has ascertained that 70% of the land within the area is organic. The set-aside areas have been adjusted by this factor.

[29] It has been assumed that the projects will be realised three years after the Finance Act appropriation.

weather data including lower emissions levels is used in 2025 compared with other years. The calculation in DCEO20 calculates emissions from forests and other land areas in all years as approximated normal years based on a three-year average of model-based calculations of emissions. Projections of emissions from land have previously taken a periodic perspective. In the future, it will be identified whether the method used is the best approach for estimating average values for the expected emissions and removals in the individual projection years.

The drainage condition of agricultural areas is crucial for emissions. New, preliminary indications suggest that agricultural areas are less drained and therefore more waterlogged than was assumed in these calculations. The Ministry of Climate, Energy and Utilities has initiated work to ensure better knowledge about how emissions from high-carbon soils can be calculated more accurately.

Emissions from forestry and other land use are generally associated with a higher methodological uncertainty than for other sectors. This is because net emissions/removals are a result of small changes in very large carbon pools, and because removals and emissions in forests depend on logging and growth rates. Moreover, emissions from other land use depend on the weather, and the emissions factor per hectare of carbon-containing agricultural soils is also subject to uncertainty.

8 Energy Balance

Among other considerations, the projection of emissions is based on detailed calculations of developments in the energy system in Denmark's climate and energy model (Figure 2).

The following sections present the main results of energy system developments regarding gross energy consumption, renewable energy share, electricity consumption and the electricity balance.

8.1 Gross Energy Consumption Is Steady, but on the Rise

Figure 29 shows that, since 1990 and up to 2030, the composition of Danish gross energy consumption is characterised by a falling consumption of coal and increasing consumption of renewable energy.

Consumption of coal is expected to be 94% lower in 2030 compared with 2018 in the absence of any new measures. This development is due in particular to expectations of a full phase-out of coal in large-scale CHP production (Chapter 3.1.1).

Gross energy consumption will increase from 2023, and this is primarily due to increasing electricity production and emerging net exports of electricity.

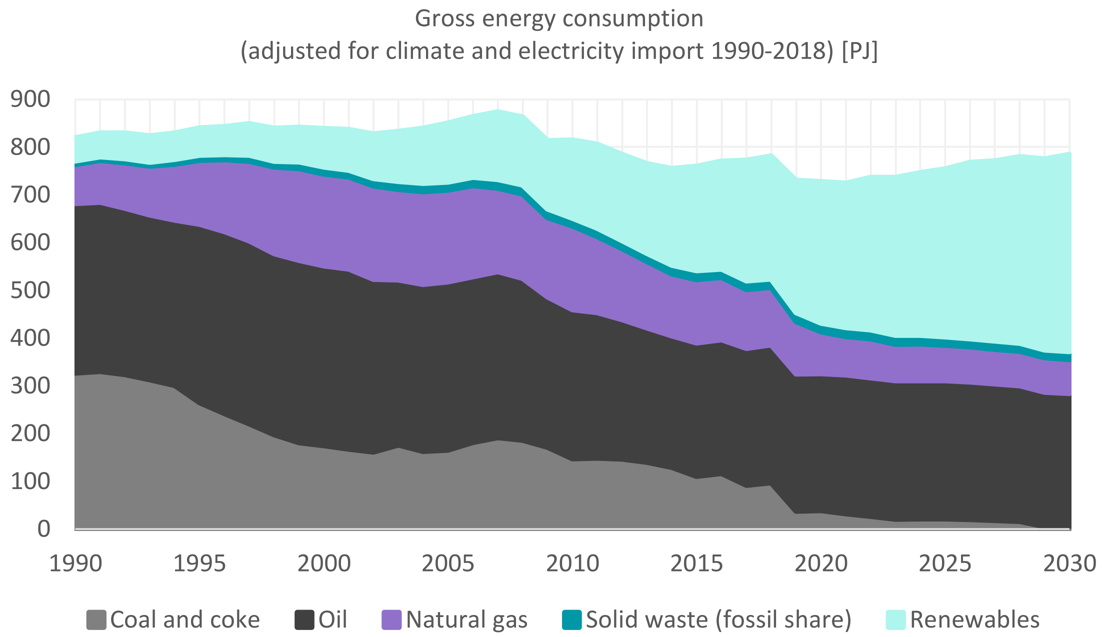


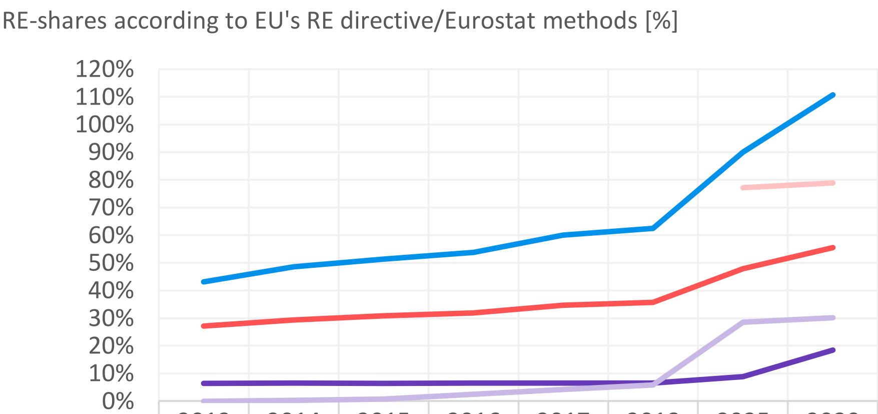
Figure 29: Gross energy consumption by type of energy 1990-2030 [PJ]. The statistical calculation for 1990-2018 has been adjusted for climate and electricity trade. The projection result for 2019-2030 is based on normal years and has not been adjusted for electricity trade, i.e. these are model calculations of observed consumption in a given normal year.

8.2 The Renewables Share Is Expected to Reach 55% in 2030

The total renewables share (RES) and the renewables share for transport (RES-T) are subject to binding national EU targets in 2020. The EU Renewable Energy Directive moreover sets out a target for 27% renewables share in the EU as a whole by 2030, but this target has not been implemented as national obligations. Instead, EU Member States are obligated to account for their contributions to reaching the common EU target in their National Energy and Climate Plans (European Commission, 2017).

Figure 30 shows that Denmark's total share of renewables (RES) is expected to rise to 55% in 2030. The share of renewables increased from 16% in 2005 to 36% in 2018.

Moreover, the renewables share of electricity consumption (RES-E) is expected to exceed 100% from around 2027 and will reach 111% in 2030.



	2013	2014	2015	2016	2017	2018	2025	2030
Total consumption (RES)	27%	29%	31%	32%	35%	36%	48%	55%
Electricity (RES-E)	43%	48%	51%	54%	60%	62%	90%	111%
District heating (RES-DH)							77%	79%
Transport (RES-T)	6%	7%	6%	7%	7%	7%	9%	19%
Mains gas (RES-G)	0%	0%	1%	2%	4%	6%	29%	30%

Figure 30: Renewable energy shares (RES) calculated according to the Renewable Energy Directive/Eurostat [%]. The renewables share in district heating (RES-DH) is not defined in the Renewable Energy Directive, but is calculated as a supplement to the other renewables shares.

This development is due, in particular, to deployment of offshore wind, onshore wind and solar PV, as well as to conversion of existing CHP plants to biomass. The assumptions for this are described in Chapter 3.1.2. A small decline in final energy consumption up to 2030, resulting from efficient energy exploitation, contributes slightly to the increase in the total renewables share.

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

The share of renewable energy in transport (RES-T) is expected to reach 19% in 2030, due in particular to increased electrification of passenger cars and vans, as well as rail transport in combination with a high share of renewable energy in electricity consumption (RES-E).[30] Chapter 1 takes stock of RES-T regarding the EU obligation in 2030. The assumptions are described in Chapter 6.

The renewables share of mains gas consumption (RES-G) is expected to increase to 29% already in 2025 and to 30% in 2030. This development reflects in particular the effect of increased amounts of upgraded biogas mixed in the gas grid. The assumptions for this are described in Chapter 3.1.4. A minor drop in mains gas consumption will contribute to a smaller extent to the increase in RES-G up to 2030.

The renewables share in district heating (RES-DH) will increase to 79% in 2030. The remaining 20% (approximately) will be due mostly to waste incineration, the emissions from which will stem from inorganic waste volumes (Chapter 5.1). The renewables share is not defined in the Renewable Energy Directive but has been calculated as described in the Glossary (Appendix 1).

8.3 Electricity Consumption Will Increase

Figure 31 shows that electricity consumption, excluding grid losses, and in the absence of any new measures, is expected to increase from 32.4 TWh in 2018 to 46.4 TWh in 2030, corresponding to an increase of 43%.

This development is due, in particular, to the establishment of new, large data centres (COWI A/S for the Danish Energy Agency, 2018). However, expected electrification of transport, space heating in households, as well as in industry and services also contribute to an increasing electricity consumption.

The expectations of new large data centres and their electricity consumption up to 2030 described in DECO19 have been maintained in this year's publication. This reflects an overall expectation for developments in this sector that is not tied to decisions by individual players concerning individual projects. The projections are based on reported data from Denmark's first large data centre, which was put into operation in September 2019 in Odense. The electricity consumption of large data centres is subject to considerable uncertainty up to 2030.

The demand for electricity for household appliances will increase steadily throughout the projection period. In 2018, electricity consumption for household appliances came to 10 TWh, and consumption is expected to increase to 11.5 TWh in 2030. The trend in electricity consumption for appliances is driven by economic growth in general which will trigger a higher level of private spending and increased use of appliances. The increased electricity

[30] A high share of renewable energy in electricity consumption (RES-E) affects calculation of the renewables share in transport (RES-T) because electricity consumption weighs more when calculating the renewables share for transport than for biofuels, for example. The Renewable Energy Directive uses a multiplication factor of four for the renewables share of electric road transport and a multiplication factor of 1.5 for the renewables share of electric rail transport (see the glossary).

consumption will be curbed to some extent by requirements in the Ecodesign Directive for energy efficiency of appliances.

This year's outlook has included an expected electricity consumption for PtX (Power-to-X) conversion technologies that interact with renewable energy sources to produce other forms of energy, such as hydrogen, methanol and jet-fuel or ammonia. The projections include an electricity consumption of 0.1 TWh from two demonstration facilities currently being established with government subsidies (Danish Energy Agency, 2019c). There will likely be no additional PtX projects in the absence of any new measures.

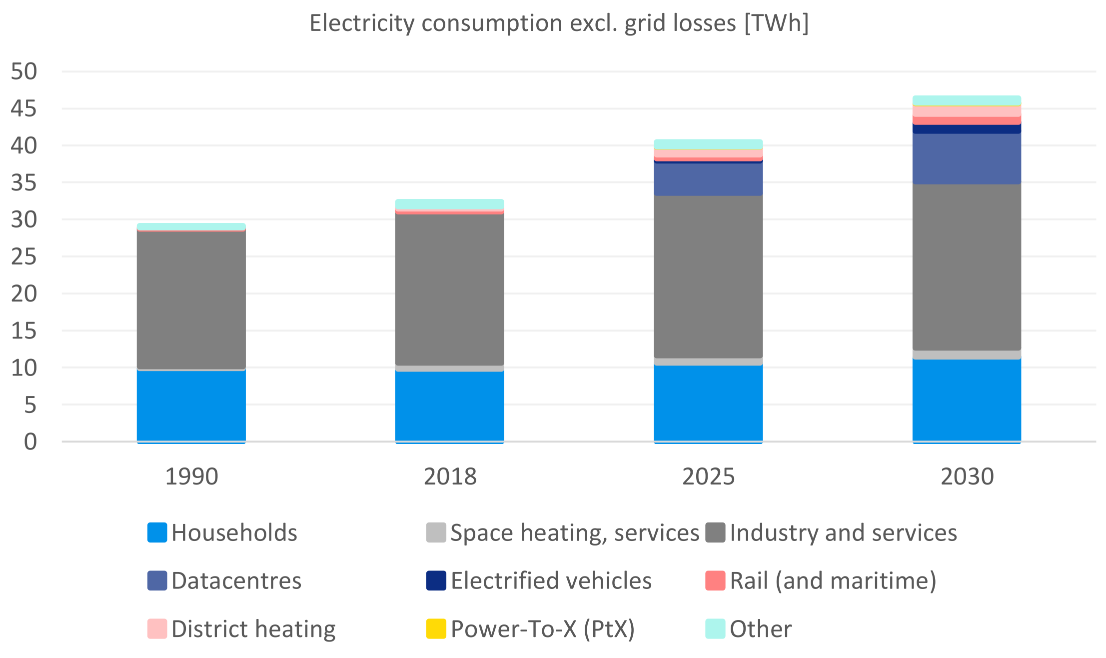


Figure 31: Electricity consumption (excluding grid losses) by consumption category 1990-2030 [TWh].

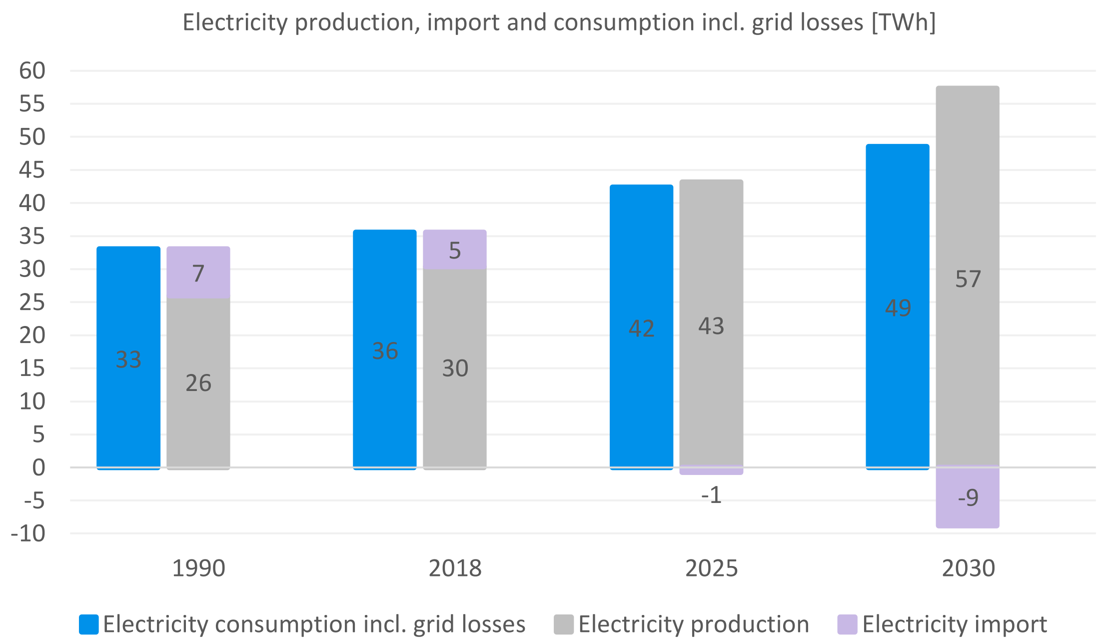


Figure 32: Electricity consumption, including transmission and distribution losses, as well as electricity production and electricity imports 1990-2030 [TWh].

8.4 Danish Electricity Balance Likely to Tip Towards Net Exports

Historically, Danish electricity consumption and production have been fairly balanced with variations in individual years due, in particular, to climatic conditions that have had an effect on the exchange of electricity with neighbouring countries.

Figure 32 shows that Danish electricity production is expected to increase more than electricity consumption, so that Denmark is expected to become a net exporter of electricity from 2025. This increase depends on the deployment of wind power and solar PV in Denmark, including Denmark's possibilities to sell electricity on high-price electricity markets in the United Kingdom, the Netherlands and Germany.

In the absence of any new measures, in 2030 net exports of electricity are expected to constitute 15% of electricity production, corresponding to 18% of electricity consumption (including grid losses).

8.5 What Will Be the Effect of Net Exports of Electricity in 2030?

Net exports of electricity in 2030 will have an effect outside Denmark.

Denmark is connected to the rest of Europe in a joint electrical system, which will be expanded in the near future (ENTSO-E, 2018).

The CO2 intensity of electricity production is already considerably lower in the Nordic countries than in Germany, the Netherlands, the United Kingdom and Poland (European Environment Agency, 2020a; IEA, 2020).

In 2030, Denmark is expected to be a net exporter of electricity. Deployment of wind power and solar PV up to 2030 will be the most important contributor to Danish electricity production exceeding electricity consumption on an annual basis after 2025.

Danish net exports of electricity will most likely contribute to replacing fossil-based electricity production in other European countries; however, it is uncertain to what extent. This effect will probably decrease over time in accordance with other European countries converting their energy supply to renewable energy.

Appendix 1. Glossary

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

Final energy consumption: Final energy consumption is energy consumption delivered to end users, i.e. private- and public-sector businesses as well as households. Uses include: manufacture of goods and services, space heating, lighting and other appliance consumption, and transport. Added to this is oil consumption for non-energy purposes, i.e. lubrication and cleaning as well as bitumen for paving surfaces. Energy consumption in connection with extraction of energy, refining and conversion is not included in final energy consumption. The definition and breakdown of final energy consumption follow the International Energy Agency's (IEA's) and Eurostat's guidelines. Energy consumption for transport by road and railway, by sea, by air, and by pipeline - irrespective of consumer - is subsequently taken out of the total final energy consumption figure as an independent main category. This means that energy consumption by businesses 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 petcoke, 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 the corporate sector, the transport sector, households, and the service sector, as well as energy products for agriculture, forestry and fisheries, including electricity and heating consumption by the energy sector in connection with electricity and heat production and including electricity and heat losses in connection with distribution and transmission. Thus, unlike final energy consumption, gross final energy consumption excludes consumption for non-energy purposes, including auto-consumption and distribution losses in energy supply, and cross-border trade. Gross final energy consumption is used as the basis for calculating renewables share.

Observed (actual) energy consumption: Observed energy consumption is found by adding distribution losses and energy consumption in connection with energy extraction and refining to final energy consumption. Added to this figure is auto-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, bioliquids, SNG, biodegradable waste and biogas). SNG is biogas that has been upgraded to meet the supply requirements for gas in the grid.

Renewables shares: Renewables shares are calculated according to the Eurostat EU calculation method. For a detailed description of this, see the Renewable Energy Directive (EU 2009) and Eurostat SHARES (Eurostat, 2019).

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

Greenhouse gases: Emissions of greenhouse gases are not measured but assessed using emissions factors linked to emission activities, such as fossil fuel consumption. 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 representation 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.

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

Greenhouse gas emissions NOT covered by the EU ETS system (non-ETS): Non-ETS emissions primarily stem from transport, agriculture, households, other industries, waste, and a number of small-scale CHP plants, i.e. numerous large and small emission sources. Regulation takes place through national measures 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 European effort is shared between Member States according to an agreement for the periods 2013-2020 and 2021-2030.

CO2 intensity: A measure of the amount of CO_2 emissions relative to economic production. Is calculated as the ratio between CO_2 emissions and economic output.

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

Indirect emissions: Indirect CO_2 is calculated on the basis of emissions of CH_4, NMVOC and CO, which oxidize to CO_2 in the atmosphere. Only fossil emissions of CH_4, NMVOC and CO are included in the calculation.

Carbon pool: Forests and other land (primarily cropland and grassland in agriculture) is an important carbon pool, as CO_2 can either be stored in or released from trees, plants and soils. The size of the carbon pool in forests and other land depends on how the land and the forests are used.

N projects: Land-based measures established to reduce nitrate leaching as a consequence of agricultural production.

Appendix 2. Abbreviations

Waste (bio)	The biodegradable share of combustible waste.
Waste (fossil)	The non-biodegradable share of combustible waste.
BF20	Denmark's Climate and Energy Outlook 2020/DCEO20
CO2-eq.	CO2 equivalents
DCE	Danish Centre for Environment and Energy, Aarhus University
ETS	The European Emission Trading System
EU+24	The 24 countries in the electricity market model are grouped into 15 electricity market areas:
GWP	Global Warming Potential
IEA	International Energy Agency
LULUCF	Land Use & Land Use Change & Forestry - statement of carbon removals and emissions linked to soil cultivation and forestry activities
%	Per cent
PPA	Power Purchase Agreement (bilateral electricity trade agreement between the producer and the consumer)
PSO	Public Service Obligations (financing system to support electricity production from renewable energy sources and small-scale CHP)
RES	Renewable Energy Share - total renewables share
RES-DH	Renewable Energy Share - District Heating – renewables share in district heating consumption.
RES-E	Renewable Energy Share - Electricity - renewables share in electricity consumption
RES-G	Renewable Energy Share - Gas - renewables share in mains gas consumption.
RES-H&C	Renewable Energy Share - Heating and Cooling – renewables share in heating and cooling consumption.
RES-T	Renewable Energy Share - Transportation – renewables share in transport consumption
RE	Renewable energy
HP	Heat pump

Appendix 3. Measures Already Included in the Calculations

The following describes elements of more recent policy measures which have been included in Denmark's Climate and Energy Outlook. See Figure 1 for an overall illustration of the time horizon for these measures. Measures from before the projection period which are in effect and have an impact during the projection period have also been included.

In principle, the Energy Agreement of 29 June 2018 (Ministry of Energy, Utilities and Climate, 2018b) covers the period up to and including 2024. However, because the last of the three offshore wind farms under the agreement is not expected to be commissioned until 2029-2030, the agreement can be interpreted to affect the entire projection period.

The new energy saving efforts scheme under the 2018 Energy Agreement (replacing the existing "energy saving efforts by energy companies" scheme due to expire at the end of 2020) has been included (Danish Energy Agency, 2019a). The scheme includes subsidy pools for energy savings in businesses and households. Furthermore, the scheme includes a campaign to raise awareness about energy savings opportunities in households. The period 2021-2024 includes a subsidy pool targeting process-energy savings in industry and services and energy consumption in buildings.

In addition, the effect of removing the cogeneration requirement and the fuel obligation in small-scale district heating areas under the Energy Agreement has also been included, as well as the new rules on establishing biomass boilers, which expire at the end of 2021. Finally, the projections also take into account the Danish Energy Agency's changed practice of providing exemption from the cogeneration requirement in large-scale district heating areas in connection with the phase out of coal (Danish Energy Agency, 2019b). The above has an effect with regard to the expected conversion of natural-gas-based and coal-based heating and CHP to other supply technologies, such as heat pumps and biomass boilers.

The Energy Agreement earmarks a financial reserve for even more renewable energy from 2025 - the so-called RE reserve. The effect of the RE reserve is not included in the DCEO20. Usage of the fund will depend on a periodic assessment of RE projects that are undertaken without funding from the reserve.

The Energy Agreement's pool for green transport for 2020 has been allocated and is included. The pool includes DKK 50 million for charging stations for electric cars and DKK 25 million to promote green commercial transport by establishing more charging and filling stations for green lorries and vans.

The Energy Agreement's relaxation of electricity taxes prolongs and expands current relaxations agreed in connection with the Agreement on Business and Entrepreneurial Measures of 12 November 2017 (Ministry of Industry, Business and Financial Affairs, 2017), which in this area mainly includes a relaxation of the tax on electric heating. Furthermore, the projections include the effect of repealing Annex 1 of the Danish Electricity Tax Act, which will allow more businesses to seek refunds for electricity taxes.

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

The agreement on a temporary relaxation of the registration tax on electric vehicles (Danish Ministry of Taxation, 2018), as well as a decision to keep the 2019 phase-in rules in 2020 (Danish Ministry of Finance, 2019), have been included with an effect on sales of vehicles up to 2022.

Earlier subsidy schemes for new onshore wind ceased in 2018 and will be replaced by technology-neutral invitations to tender (Danish Energy Agency, 2020d). The technology-neutral tendering procedures conducted in 2018 and 2019 have been included with the effects achieved. Upcoming technology-neutral tendering procedures have been included as an element in the Energy Agreement and have been distributed across technologies as appropriate.

For biogas, biomass-based CHP and electricity produced from burning biomass, existing facilities established under earlier subsidy schemes will continue under existing terms and conditions. However, the 2018 amendment to the Promotion of Renewable Energy Act and to the Electricity Supply Act stipulates a revised price supplement for biomass-based electricity generation based on facility-specific depreciation in accordance with EU state aid rules (Danish Energy Agency, 2020c).

A scheme has been established for existing biomass-based CHP which ensures that producers will be reimbursed the additional cost of using biomass instead of fossil fuels as long as the installation has not been depreciated. When the installation has been fully depreciated, the producer can still obtain support, but at a lower rate. The scheme for depreciated installations runs from 2020 to 2029 and reimburses producers for their additional costs of using biomass instead of fossil fuels.

When the installation has been fully depreciated, the producer can still obtain subsidies, but at a lower rate. The scheme runs from 2020 to 2029 and reimburses producers for their additional costs of using biomass instead of fossil fuels.

Furthermore, production-independent support for small-scale CHP production (the so-called basic amount) (Danish Energy Agency, 2018a) and support for establishing large electric heat pumps ended at the end of 2018 (Ministry of Climate, Energy and Utilities, 2017).

The 2018 Energy Agreement set aside DKK 111.4 million annually for the years 2020 and 2021 to support the establishment of centralised, electric heat pumps, solar heating systems and biomass boilers at district heating plants which have received basic subsidies. The objective of this pool is to make up for the price increases expected to follow after the basic subsidies cease at the end of 2019. Subsidies can only be granted if the installation which would receive support primarily replaces district heating production based on fossil fuels. The subsidy scheme has yet to be realised.

In March 2019, the Danish Parliament established an agreement on increased exploitation of surplus heat (Ministry of Climate, Energy and Utilities, 2019). This agreement included an initiative to simplify the existing rules and reduce the tax on surplus heat to a fixed tax rate of DKK 25 per GJ. The agreement moreover introduced a new certification scheme allowing businesses to obtain a lower tax rate of DKK 10 per GJ and a transitional scheme for businesses that supplied surplus heat from before 1995. The parties to the agreement also agreed to prepare a new price regulation model.

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

Projections pertaining to land use and forests (LULUCF) include the planned deployment of catch crops in agricultural production under the 2020 nitrogen efforts agreement (Ministry of Environment and Food of Denmark, 2019) and the allocation of funds decided under the rural development programme up to and including 2021, including funds for setting aside organogenic land and establishing wetlands. From 2022, only 240,000 ha of mandatory catch crops have been included. Furthermore, measures aimed at establishing more wetlands and setting aside organogenic land adopted under the Finance Act for 2020 up to and including 2029 have been included. This means that future measures to protect the aquatic environment, including continuing the targeted regulation efforts after 2021, will not be included until the measures have been politically adopted.

In general, for agriculture the projections also take account of the effect of the current nitrogen and ammonia regulations, which will contribute to curbing greenhouse gas emissions from agriculture through various measures.

Specific knowledge about research and development projects, including wind turbine demonstration projects, has also been included. For example, PtX (Power-to-X) technologies have been included based on existing knowledge about demonstration projects supported by the Danish Energy Agency (Danish Energy Agency, 2019c).

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

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

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

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

Appendix 4. Assumptions Agriculture, Forestry and Other Land Use

Agriculture

- The number of dairy cows, calves, heifers, bulls and bullocks is assumed to increase slightly, while the number of suckler cows is expected to fall. The number of piglets is expected to increase due to production efficiency in the form of more piglets per sow per year and because exports of piglets are expected to increase additionally up to 2030, which means production of slaughter pigs will likely fall. Differences relative to previous reports are monitored regularly (Jensen, 2017).
- The milk yield is expected to increase due to an enhanced genetic potential, and this will lead to an increase in feed consumption and, thus, increased emissions per dairy cow from digestion.
- With regard to environmental technologies, it has been assumed that the use of slurry cooling, in-house slurry acidification and air purification in pig and cattle housing systems will increase. Projections for this are based on the proportionate distribution from a historical statement of livestock approvals. Frequent mucking-out at mink farms and the use of heat exchangers in broiler poultry farming are also on the rise. The use of slurry acidification in connection with slurry application has also been included.
- The amount of pig and cattle slurry assumed to degasify in biogas plants will increase in proportion to the expected increase in biogas production up to 2030.

Forests, agricultural areas and other land use

- The total area of agricultural land is expected to be reduced slightly.
- A total of 1,900 hectares of forest will be planted each year.
- The area of land that is built upon will increase by 1,500 hectares every year.
- Reconfiguration of agricultural areas: With the current nitrate scheme and organogenic soils scheme under the rural development programme, 1,500 ha/year (n+3 years) will be reconfigured up to and including 2021. It is assumed that the 2020 Finance Act agreement (the pool of DKK 2 billion) will lead to the reconfiguration of 1,500 ha/year over the period 2020-2029. Note that the climate impact will not be calculated until three years after the year of granting. Changes to the area of land will therefore occur three years after financing.
- Catch crops: Up to 2021, the area will increase to 490,000 ha/year. From 2022, the area of catch crops is assumed to be 240,000 ha/year (i.e. the mandatory catch crops). The planned deployment of catch crops under the 2020 nitrogen efforts agreement has been included. Future measures to protect the aquatic environment, including continuing targeted regulation efforts, will not be included until the measures have been politically adopted.
- It is assumed there will be an increase in yields from cereal crops of 0.6% per year. The significance of other crop changes is marginal.

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