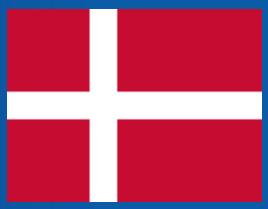
IEA Bioenergy
Technology Collaboration Programme

Implementation of bioenergy in Denmark - 2021 update



Country Reports

IEA Bioenergy: 10 2021

This report was prepared from the 2021 IEA World Energy Balances and Renewables Information, combined with data and information provided by the IEA Bioenergy Executive Committee and Task members[1]. Reference is also made to FAOstat and Eurostat data as well as data from national statistics. All individual country reports were reviewed by the national delegates to the IEA Bioenergy Executive Committee, who have approved the content. General background on the approach and definitions can be found in the central introductory report for all country reports.

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HIGHLIGHTS

- Renewables make up 36% of Denmark's total energy supply in 2019. Bioenergy plays an important role, representing three quarters of renewable energy supply.
- The main application of bioenergy is in renewable heat, both in direct heating and in district heating (which is highly developed in Denmark). There was a clear and consistent trend to replace fossil fuels by biomass in district heating plants; more than 60% of district heating is now produced from biomass.
- Straw plays a significant role, but also imported woody biomass (chips, pellets) and waste fractions.
- The Danish power production has taken major steps towards renewable energy, with the share of fossil fuels going down from 66% in 2010 to 20% in 2019. Major growth was in wind energy, which now represents more than half of Danish power production. The share of bioelectricity is also relevant with 20%, which is mainly produced in CHPs.
- Diesel is the dominant transport fuel in Denmark, and its consumption is in fact still increasing. The role of biofuels in transport is relatively stable around 5% in the past decade, with a general application of B7 as diesel fuel (*containing up to 7% biodiesel by volume*) and E5 as gasoline fuel (*containing up to 5% bioethanol by volume*).

[1] While data for 2020 are starting to become available at national level, it was decided to consider trends up to 2019 for good comparability and benchmarking between the different IEA Bioenergy member countries. Care should also be taken when using 2020 data for analysing trends as these data are distorted by the COVID19 Pandemic.

- There has been a strong increase of biogas in the past decade, which already represents more than 15% of overall gas consumption.
- Denmark has implemented a national legally binding Climate act to meet 70% GHG reduction by 2030 and be climate neutral in 2050.

COUNTRY PROFILE

Population and land use

Denmark is the southernmost of the Scandinavian countries and is member of the European Union. It has a total land area of 40 thousand km² and a population of 5.8 million people. This represents a relatively high population density of 144 persons per km².

The country is relatively flat with little elevation. A very high share (60%) of the land area is arable land. Only 16% of the land area is forest land.

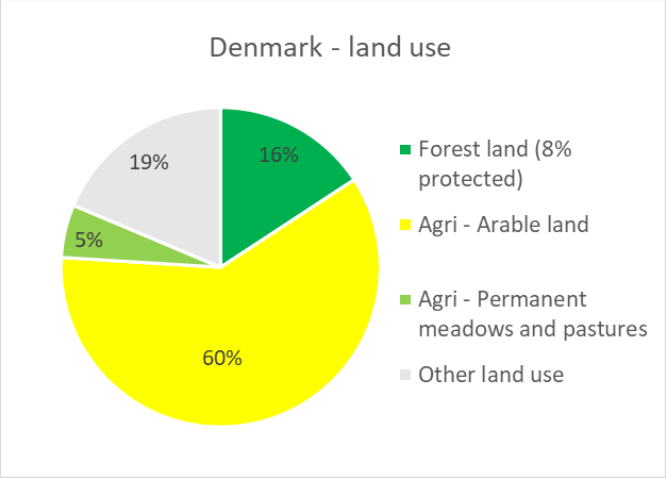


***Figure 1**: Land use in Denmark (2018 figures - Source: FAOstat)*

Final energy consumption

Overall final energy consumption in Denmark (*also including non-energy use of oil, natural gas and coal in industry*) equates 2.34 tonnes of oil equivalent (toe) per capita, which is around the average of IEA Bioenergy member countries. The share of industry in final energy consumption is low compared to other countries. Around half of final energy consumption is in the residential sector and services.

***Table 1**: Distribution of the final consumption of energy carriers by sector in Denmark (2019 figures - Source: IEA (2021) World Energy Balances and Renewables Information)*

Final consumption energy carriers	Toe/capita (2019)	% of total	*Median* (toe/capita)*
Industry (energy use)	0.39	16%	*0.67*
Industry (non-energy use)	0.03	1%	*0.21*
Transport	0.74	32%	*0.69*
Residential	0.72	31%	*0.57*
Commercial & public services	0.34	14%	*0.34*
other	0.12	5%	
Total	2.34		*2.34*

** Median of the 25 member countries of IEA Bioenergy*[2]

[2] Comparative figures of the different IEA Bioenergy member countries are discussed in the central Countries' Report.

NATIONAL POLICY FRAMEWORK IN DENMARK

TARGETS AND STRATEGIES

Denmark has obligated to follow both international and national binding targets for 2030 and 2050 to achieve the goals of the Paris agreement. European Union's 2030 Climate target plan and the Climate Act, adopted by the Danish Parliament, have defined specific sets of targets shown in Table 2 together with other national goals.

Table 2: Renewable energy and climate targets in Denmark [1]

Policy	Goals	Reference year	Year of completion
EU – 2030 Climate Target Plan	40% GHG reduction for EU	1990	2030
	43% GHG reduction for emissions included in the EU ETS (Emission Trading Scheme)	2005	2030
	30% GHG reduction from buildings, agriculture and transport		
	Min. 27% renewable energy	-	
	Min. 27% energy efficiency	-	
National goals / Climate Act	70% GHG reduction	1990	2030
	Min. 55% of energy consumption originates from RE	-	
	90% of district heating is based on other sources than coal, oil and gas.	-	
	100% electricity originates from renewable sources	-	
	GHG neutrality	-	2050

As a part of the European Green Deal, the commission has proposed to raise the 2030 GHG reduction goal to 55% compared to 1990, instead of the current 40%.

With the Danish Climate Act, the reduction targets will become legally binding and it sets a number of frameworks that obligates current and future Minister of Climate to take action to achieve the GHG reduction goals. Each year, the Climate Council must provide a professional assessment of whether the government is on the right path towards the goals of the Climate Act.

In 2020 a climate agreement was agreed on, with the purpose to develop, expand, and integrate green technologies in the energy sector and industry [2]. The strategy relies on high levels of electrification across the energy sectors. Some of the main topics from the agreement are:

- Development of the world's first energy islands to provide electricity for higher levels of electrification in the energy sectors and to facilitate Power-to-X (PtX).
- Construction of several windmill farms.
- Pools have been established to promote the development of carbon capture storage and utilization, which is expected to contribute to GHG reduction before 2030.
- Promote PtX.
- Promote higher levels of electrification of the industry and raise the energy efficiency of processes that cannot be electrified.

- Promote RE in the heating sector by lowering tax for electricity and raising tax for fossil fuel used for heating. In addition, efforts should be made to promote sector coupling of district heating.
- Specific sustainability requirements for wood biomass.

A description of renewable energy and climate policies and measures in Denmark is available at the IEA's Policies and Measures Database: https://www.iea.org/policies?country=Denmark

Specific policies related to renewable electricity, renewable heat and transport biofuels will be highlighted in the chapters about the role of bioenergy in different sectors.

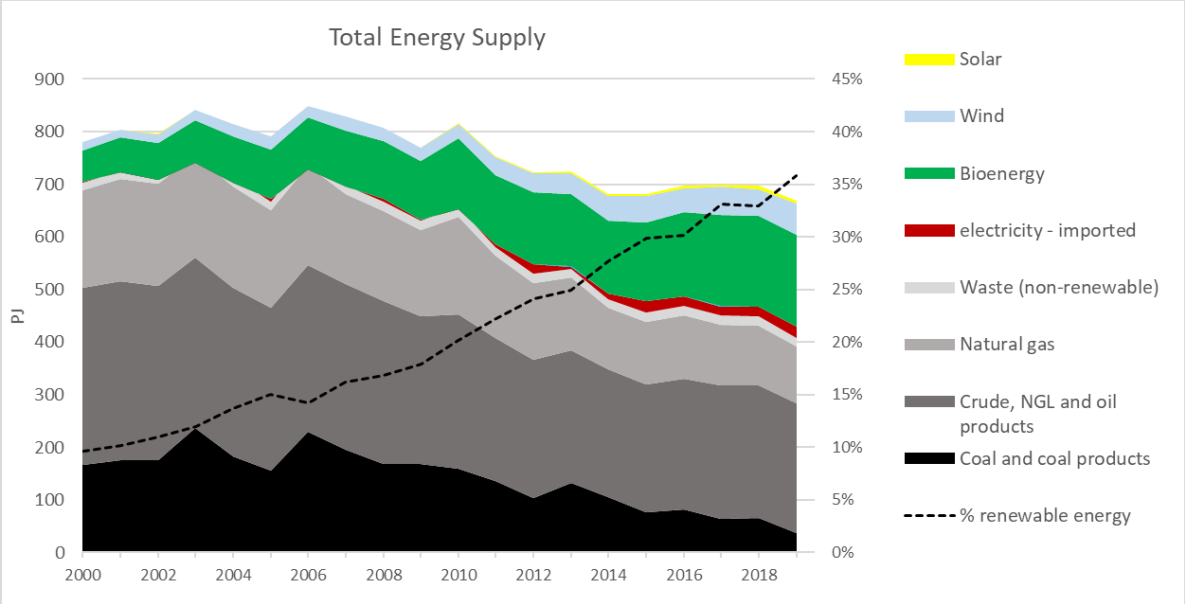
THE CONTRIBUTION OF BIOENERGY IN NATIONAL ENERGY SUPPLY

TOTAL ENERGY SUPPLY

The total energy supply (TES) of Denmark in 2019 amounted to 669 petajoule (PJ) with fossil fuels (oil, gas, coal) contributing 58%. Oil products account for 37% of TES (247 PJ); natural gas accounts for 16% (107 PJ), coal products for 5.5% (37 PJ) and non-renewable waste 2.7% (18 PJ). Renewable energy sources have a share of 36% or 240 PJ – 175 PJ bioenergy, 58 PJ wind energy and 6 PJ solar energy. 21 PJ of electricity is imported, which represents 3% of Danish TES.

Between 2006 and 2013 total energy supply in Denmark had a declining trend, stabilizing around 700 PJ after 2013. In the past years there was a clear trend to shift from fossil fuels to renewable energy. Compared to 2010 the share of coal in TES has gone down from 20% to 5.5%, natural gas decreased from 22% to 16%, while oil was stable around 36%. In the same period the share of renewable energy steadily increased from 20% to 36% of TES.

The total supply of renewable energy sources in 2019 is dominated by biomass and wind energy. The share of solar energy is still relatively small. The overall share of bioenergy in total energy supply increased from 20.3% to 26.2% compared to 5 years earlier, while solar and wind combined increased from 7.4% to 9.6%.



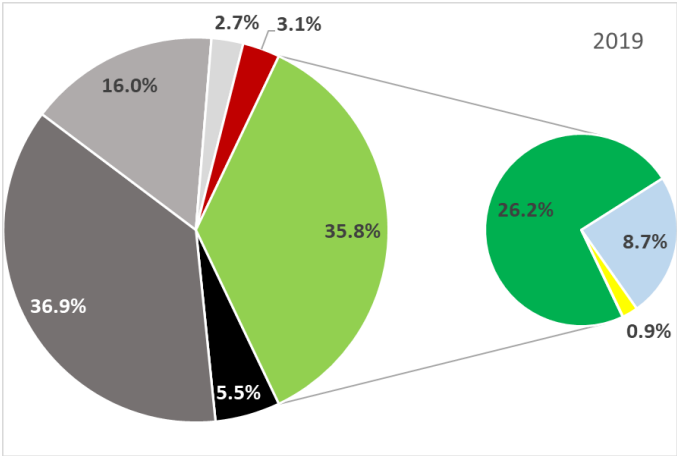


***Figure 2**: Total energy supply[3] and the contribution of different energy sources in Denmark, with distribution in 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

As shown in Figure 3, solid biofuels represent the major part (75%) of bioenergy in Denmark. They include fuel wood, wood chips, wood pellets and straw. The other bioenergy types are renewable MSW (12%), biogas (7.5%), biodiesel (4%) and biogasoline (1%).

[3] Total energy supply refers to the use of resources. In terms of the role in the energy system this distribution may overestimate the role of resources producing electricity with a high share of unused waste heat (like power condensing plants).

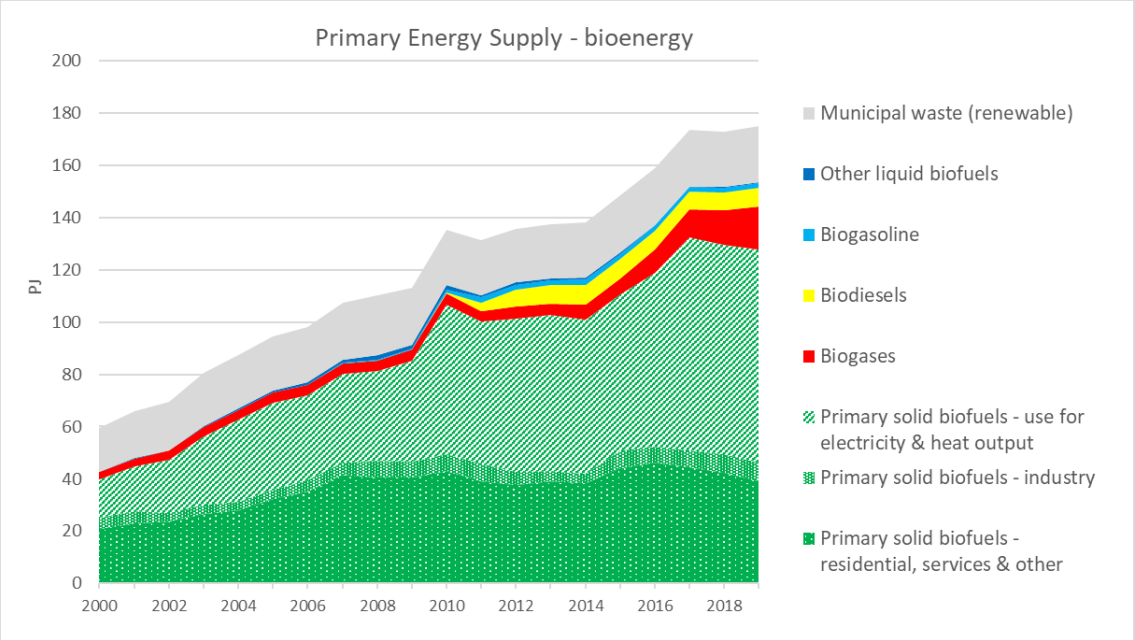


***Figure 3**: Development of total energy supply from bioenergy in Denmark 2000 – 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

Evolution of the bioenergy carriers:

- There was a consistent growth of solid biofuels, growing from 40 PJ in 2000 to 127 PJ in 2019. The main increase was in CHP and heat plants, particularly replacing fossil fuels for district heating. The use of solid biofuels in residential applications is quite stable. The use in industry is marginal.
- Energy from renewable MSW is fairly stable around 21 PJ since 2005.
- There was a solid base of biogas around 4 PJ up to 2012. After 2012 biogas saw a strong growth up to 17 PJ in 2019.
- The main growth of transport biofuels was between 2010 and 2012 up to 9 PJ and has stabilized since.

Table 3 displays the 2019 total bioenergy supply values on a per capita basis. Compared to the other 24 member countries of IEA Bioenergy (expressed per capita), Denmark ranks at the top for renewable MSW, at second place for biogas (after Germany), at the high end for solid biomass and in the middle for liquid biofuels.

***Table 3**: Total energy supply per capita in 2019 for different bioenergy carriers*

	Supply per capita	*Median IEA Bioenergy members*
Bioenergy	30.4 GJ/cap	*10.6*
Solid biofuels	22.1 GJ/cap	*7.0*
Renewable MSW	3.8 GJ/cap	*0.8*
Biogas	2.9 GJ/cap	*0.7*
Liquid biofuels	1.6 GJ/cap	*1.5*

Source: IEA (2021) World Energy Balances and Renewables Information

Table 4 indicates the amounts of the different bioenergy carriers compared to some relevant reference points, namely the amount of forest in the country (for solid biomass), the amount of generated MSW (for renewable MSW used for energy), the amount of natural gas consumed in the country (for biogas) and the amount of fossil oil products consumed (for liquid biofuels).

***Table 4**: Comparison of the supply of different bioenergy carriers in 2019 to specific reference points*

	Compared to reference points		*Median**
Bioenergy	26.2 %	of total energy supply	*7.2 %*
Solid biofuels	222.3 GJ/ha_forest	compared to the domestic hectares of forest land (excl. protected)	*21.3 GJ/ha_forest*
Renewable MSW	4.85 GJ/ton_MSW	compared to the total generated MSW in the country	*1.4 GJ/ton_MSW*
Biogas	0.155 GJ/GJ_NG	compared to natural gas supply	*0.023 GJ/GJ_NG*
Liquid biofuels	0.037 GJ/GJ_oil	compared to oil products supply	*0.028 GJ/GJ_oil*

Source: energy data from IEA (2021) World Energy Balances and Renewables Information; forest figures from FAOStat; waste figures from World Bank
** median of the 25 member countries of IEA Bioenergy*[4]

Specific comments in relation to the reference points:

- The amount of solid biofuels compared to the domestic forest area is very high (~11.7 tons_dry mass of wood per hectare[5]). The forest area in Denmark is quite low, but most use of solid

[4] Comparative figures of the different IEA Bioenergy member countries are discussed in the central Countries' Report.
[5] Counted with a typical calorific value of wood (dry mass) of 19 GJ/ton$_{\text{dry mass}}$

biofuels in Denmark is not linked to the domestic forests. There is important use of straw for energy production; imported wood fuels also have a significant role.

- The use of renewable MSW for energy production is substantial compared to the available waste in Denmark. This is also at the high end compared to other European countries with well-developed waste management systems.
- Biogas already represented more than 15% of overall gas consumption in 2019.

ROLE OF BIOENERGY IN DIFFERENT SECTORS

OVERVIEW

The overall share of renewables in **final energy consumption** among electricity, transportation and heat sectors is 37%, with bioenergy making up 26% of the energy share (Table 5). Mind that these figures are slightly different from the shares in total energy supply (where unused waste heat, e.g., in fossil power production, is also included).

***Table 5**: Role of bioenergy and renewable energy in electricity, transport energy and fuel/heat consumption in 2019*

Sector	Share of bioenergy	Share of renewable energy	Overall consumption
Electricity[6]	16.8%	65.3% *(45.7% wind)*	35.3 TWh (127 PJ)
Transport energy (final consumption)	5.0%	5.7%	179 PJ
Overall fuel and heat consumption[7]	Direct biomass: 16.47% Biobased heat: 27.1%	43.8%	295 PJ
TOTAL FINAL ENERGY CONSUMPTION*	**26.5%**	**36.9%**	**600 PJ**

Source: IEA (2021) World Energy Balances and Renewables Information

The following paragraphs consider the evolutions in the different sectors.

[6] Renewable electricity production compared to final consumption. Potential renewable shares of imported electricity are not included.

[7] This includes final consumption of fuels and heat in industry, the residential sector, commercial and public services, and agriculture/forestry. Transport fuels are excluded. Energy used for transformation and for own use of energy producing industries is also excluded.
Electric heating (direct or through heat pumps) is not included in these figures as this is not separately reported.

ELECTRICITY

The Danish power production has taken major steps towards renewable energy, which is exceptional for a country without major hydropower opportunities. The share of fossil fuels (predominantly coal) in electricity consumption went down from 48% in 2010 to less than 10% in 2019. Major growth was in wind energy, which now represents around 45% of Danish electricity consumption. Nevertheless, the share of bioenergy is also relevant with 17%, which is mainly produced in CHPs. Mind that the reduction in fossil power generation also led to an increasing share of electricity imports - 16% in 2019 - to fulfil domestic electricity demand.

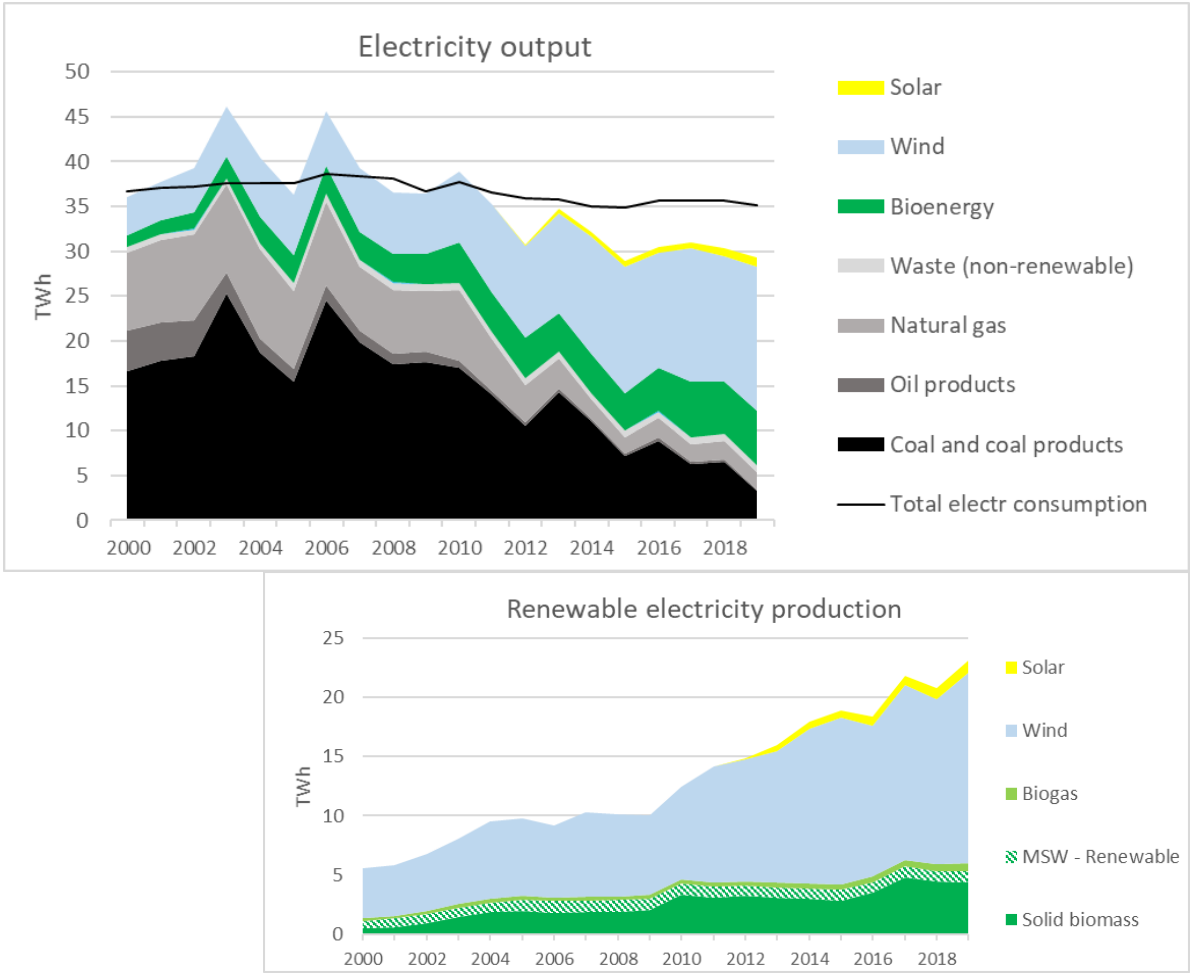


***Figure 4**: Evolution of the electricity mix in Denmark 2000 - 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

Policy framework

In 2018 it was agreed that by 2030 Danish electricity should be based on 100% renewable sources [3]. The development towards more renewable electricity has been facilitated by various subsidies defined in the Renewable Energy law (RE Law [4]), which have resulted in high increase of wind energy. Onshore wind energy has been subsidised with fixed and variable subsidies, where offshore wind energy have been put out to tender, at which a stable settlement price is decided.

Even though wind energy is the primary renewable electricity source in Denmark bioelectricity is also increasing. The bioelectricity is mainly produced from combustion of biomass and utilization of

biogas. The RE law also include subsidies for producing electricity from biomass and biogas. The subsidy for electricity production from biomass expired in 2019, however, non-depreciated plants can still receive subsidy. Another driving factor for producing bioelectricity is that it is excused from CO_2 taxes [5].

HEAT/FUEL

Figure 5 shows the role of different fuels/energy carriers for providing heat in different sectors (industry, residential sector, commercial and public services and other). It also includes heat sold to customers, e.g., through district heating. Fuel use by energy producing industries for transformation and for own use is excluded. Mind that electric heating (direct or through heat pumps) is not included in these figures as this is not separately reported in the IEA database.

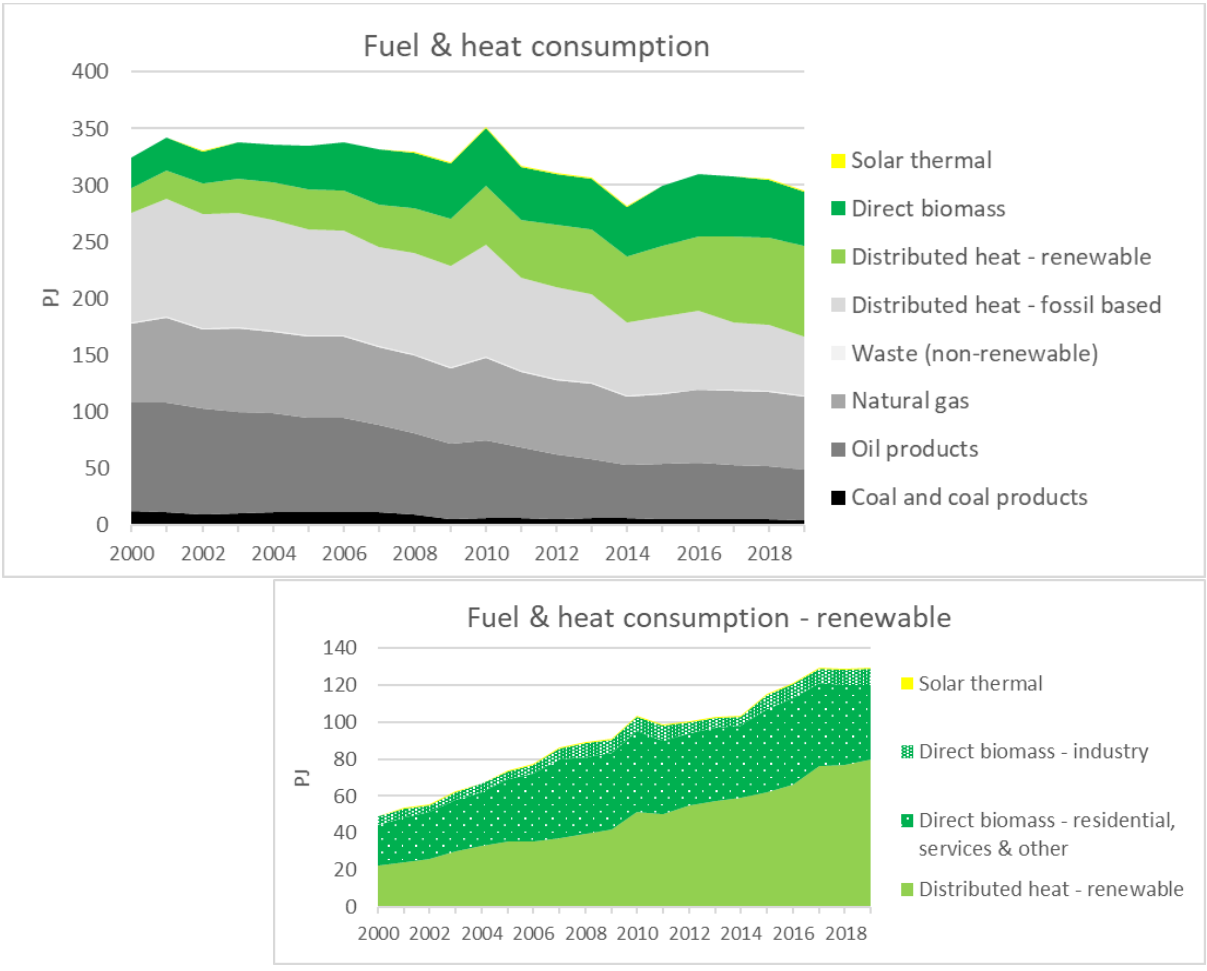


***Figure 5**: Evolution of fuel and heat consumption in Denmark 2000 - 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

The provision of fuel/heat in Denmark is for 38% based on direct use of fossil fuels (natural gas, oil, and a small fraction of coal in industry), for 45% on distributed heat (which is partly fossil, partly renewable, see further) and for 16% based on direct use of biomass. Direct use of natural gas and oil have stabilized since 2014.

Heat sales – e.g., through district heating – are particularly important in Denmark. Heat output generated and sold by CHP plants and heat plants represented 45% of fuel/heat provided in 2019, of which 60% was produced from biomass. The share of biomass in district heating has consistently grown in the past decades where particularly coal and natural gas were replaced with biomass.

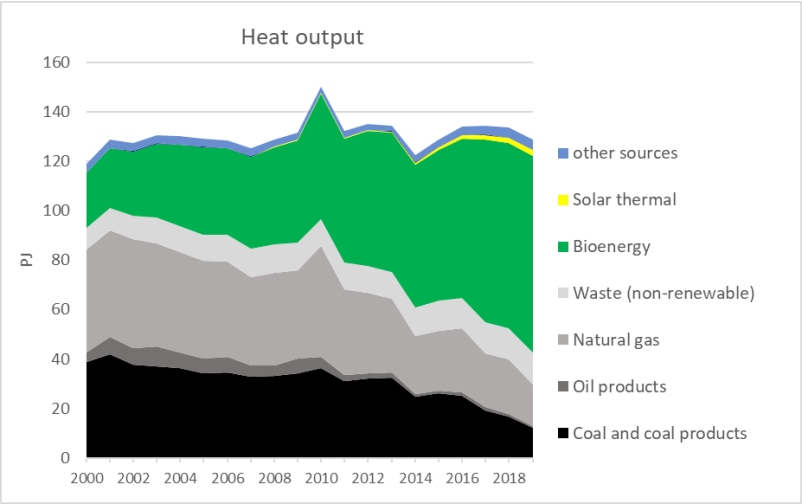


***Figure 6**: Evolution of fuels for heat output in Denmark 2000 - 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

Policy framework

In 2018, it was agreed that by 2030 minimum 90% of Danish district heat should be based on other sources than coal, oil, and gas [3]. This is also reflected in the development, as these fossil sources have been declining greatly and substituted with biomass. There are no subsidies for producing bio-heat, however, as most of the district heating is produced in CHP plants, the subsidy for producing bioelectricity has indirectly affected the production of using biomass as heat source. Furthermore, there are no energy- and CO_2 taxation for using biomass as heat source [5].

In 2013, oil boilers were banned in new buildings and by 2016 it was no longer allowed to get a new oil boiler in existing buildings if it was possible to use district heating or natural gas instead. [6]

TRANSPORT

Figure 7 shows an overview of the energy used in transport in Denmark, split up by different fuels/energy carriers.

Diesel is the dominant transport fuel in Denmark, and its consumption was in fact still increasing until recently. Between 2010 and 2012 there was a strong increase of biofuels, but this has rather stabilized after 2012 at around 5% of overall transport energy consumption. The main biofuel is biodiesel, which is consistent with the dominance of diesel fuels in Danish transport. On average biodiesel represents 6.3% by energy of diesel consumption (which is consistent with a widespread use of B7). Bioethanol on average represents 3.3% by energy of gasoline (which is consistent with a widespread use of E5).

Electricity represents a share of 0.9% of total transport energy use. This is mostly in rail - the use of electricity in road vehicles is still marginal in 2019 (0.11% of total transport energy use) but can be expected to grow in the coming years.

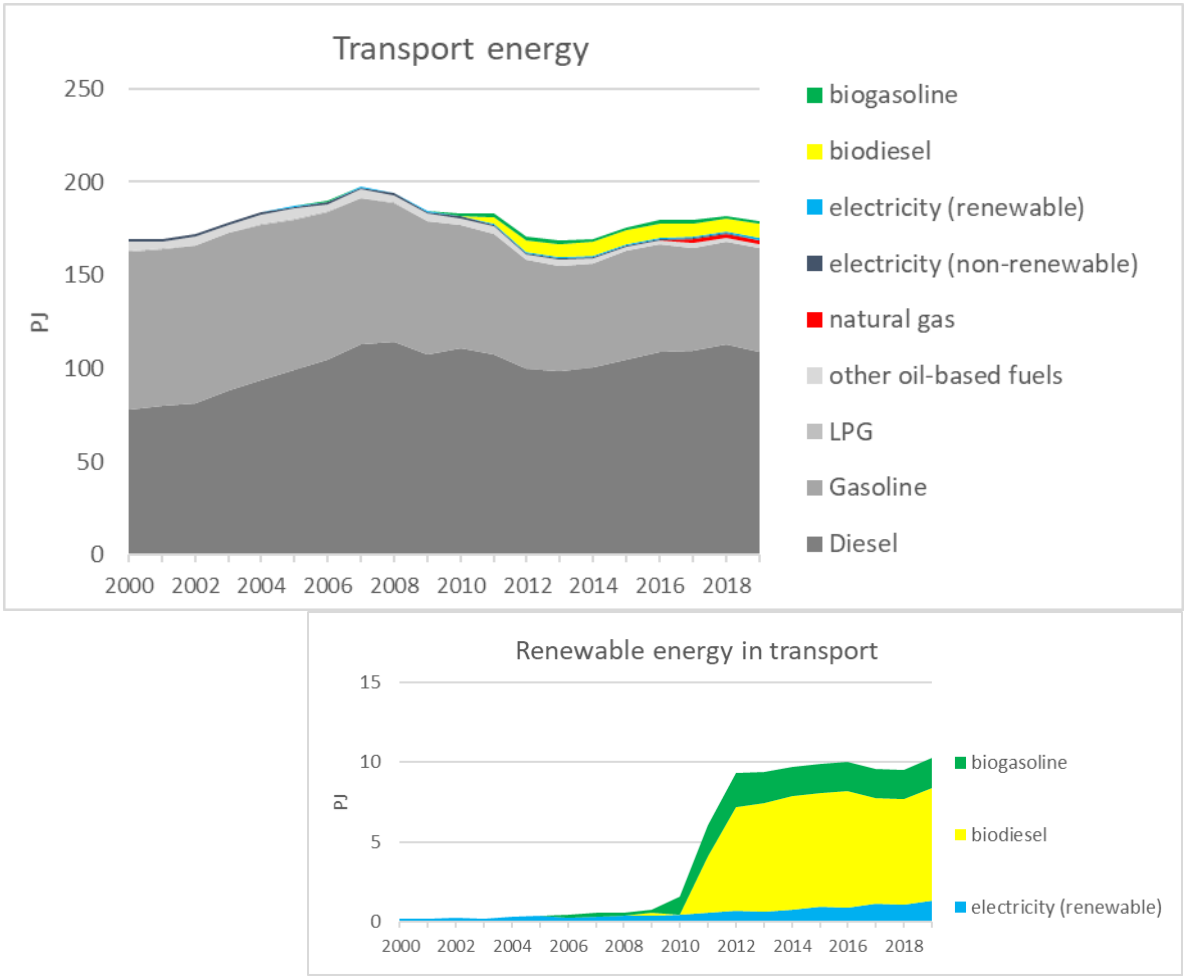


***Figure 7**: Evolution of transport fuels in Denmark 2000 – 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

Policy framework

The law of sustainable biofuels from 2010 states that 5.75% of fuel should originate from sustainable sources. For 2020 this was increased to 7.6% [7], following European counting rules (which includes multiple counting of advanced biofuels and renewable electricity).

COMPARISON WITH RENEWABLE ENERGY TARGETS

According to Eurostat[8], the following renewable energy shares in *gross final energy consumption* were reached.

Table 6: Share of renewables in different sectors in Denmark, according to Eurostat, and compared to the 2020 target

	2005	2010	2015	2019	*2020 target*
Overall share	16.0%	22.1%	29.6%	37.2%	*30%*
In heating & cooling	22.8%	31.0%	40.1%	48.0%	*40%*
In electricity	24.6%	32.7%	51.3%	65.4%	*52%*
In transport	0.4%	1.1%	6.7%	7.2%	*10%*

Denmark already reached its overall 2020 renewable energy target around 2015 and will significantly exceed targets in heating & cooling and electricity. It is likely that Denmark will apply statistical transfers to other European countries that have not reached their 2020 target.

Mind that some of these figures can differ from the IEA derived data because of different accounting rules. Particularly in transport the Eurostat shares are higher, which is due to the multiple counting of advanced biofuels and renewable electricity towards the transport target. The heating & cooling figure in Eurostat also includes heat pumps.

RESEARCH FOCUS RELATED TO BIOENERGY

Significant research, development, and demonstration activities have accompanied the transition to the higher level of bioenergy utilisation that Denmark has now attained. Danish stakeholders have for 30 years collaborated in national as well as international projects. Research has taken place in several universities as well as in national sectoral research laboratories while the application for instance has taken place in collaboration between companies and institutes.

Danish research activities within bioenergy cover a broad range of topics with specific relevance to the Danish energy system, selected examples are:

- Biomass supply, handling and pretreatment
- Biomass combustion, materials, corrosion, fouling, efficiency, primary and secondary emission abatement
- Biogas, processes, efficiencies, feedstock base, methane slip, emissions
- Liquid biofuels, 2G ethanol, RME
- Thermal biomass gasification and pyrolysis, process refinement
- MSW, determination og biological fraction

[8] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_ind_335a&lang=en

An overview of finalised and ongoing projects within research, development, and demonstrations can be found at https://energiforskning.dk. This is a website for all Danish research, development, and demonstration funding programmes within energy and climate.

RECENT MAJOR BIOENERGY DEVELOPMENTS

Coal combustion in Copenhagen is history

The inauguration of Unit 4 at the Amager plant in Copenhagen on August 26, 2020, marked the end of coal combustion to generate power and district heating in Copenhagen and an important step towards climate neutrality of the capital. Unit 4 is one of the World's largest circulating fluidised bed boilers operating solely on wood chips and has a capacity of 400 MJ/s heat and 150 MW electricity with an option to bypass the turbine to generate 550 MJ/s heat when needed. The unit replaces the coal fired Unit 3 from 1989 that was the last coal fired unit in operation in Copenhagen [8].

Biogas replaces natural gas in the grid

Due to very favourable subsidies to build and operate biogas plants, Denmark has seen a tremendous growth in generation of biogas based on manure, energy crops, and industrial feedstock. While biogas was previously used directly for CHP generation, the raw gas is now primarily upgraded and fed into the national gas grid. By the end of 2020, the share of biogas-based methane in the gas grid was above 20% [9].

Legal requirements for woody biomass

In 2020 the Danish government agreed to implement a law concerning sustainable wood biomass. The law states that it must be verified and documented that wood for heat and electricity purposes meets various sustainable criteria [10].

Still expanding biogas sector

In 2019 the construction of one of the biggest biogas plants in Europe was initiated in Kliplev, Denmark. By 2022 the plant will be operating at full capacity, producing 41 million cubic meters methane per year [11].

LINKS TO SOURCES OF INFORMATION

[1] Danish Energy Agency, “Dansk klimapolitik,” [Online]. Available: https://ens.dk/ansvarsomraader/energi-klimapolitik/fakta-om-dansk-energi-klimapolitik/dansk-klimapolitik.

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[3] Danish Ministry of Climate, Energy and Utilization, “Energiaftale,” 2018. [Online].

[4] Danish Ministry of Climate, Energy and Utilities, *Bekendtgørelse af lov om fremme af vedvarende energi (VE-loven).*

[5] The Danish Ministry of Taxation, *Bekendtgørelse af lov om kuldioxidafgift af visse energiprodukter (CO2-loven).*

[6] The Danish Parliament, *Lov om ændring af lov om varmeforsyning, lov om elforsyning og byggeloven.*

[7] Danish Ministry of Climate, Energy and Utilities, *Bekendtgørelse af lov om bæredygtige biobrændstoffer og om reduktion af drivhusgasser (Biobrændstof loven).*

[8] HOFOR, “Om Amagerværket,” [Online]. Available: https://www.hofor.dk/baeredygtige-byer/amagervaerket/om-amagervaerket/.

[9] M. Hadrup, “Biogas i gasnettet fordoblet på et år,” *GASenergi,* 2021.

[10] Danish Ministry of Climate, Energy and Utilities, “Politisk aftale om lovkrav til træbiomasse,” 2020. [Online]. Available: https://kefm.dk/aktuelt/nyheder/2020/okt/politisk-aftale-om-lovkrav-til-traebiomasse.

[11] Sustainable Bio Solutions, [Online]. Available: https://www.sbskliplev.dk/.