Denmark 2023

Energy Policy Review

International Energy Agency

INTERNATIONAL ENERGY AGENCY

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Executive summary

Denmark has been an early leader in decarbonisation and is inspiring many countries around the world. The technological transformation of Denmark's energy system is fast and visible, notably in electricity with offshore wind, biomethane, district heating, and carbon capture and storage (CCS) development.

Denmark has the highest share of wind electricity (54%) in the IEA, which together with bioenergy and solar photovoltaic (PV) make up 81% of the power mix. The district heating sector has practically phased out coal, helping lower the reliance on fossil fuels in Denmark's total energy supply (TES) from 75% in 2011 to 53% in 2022, well below the IEA average of 79%.

Denmark is committed to ending fossil fuel production by 2050. Reaching 100% biomethane in heating before 2030 has become a key priority since Russian Federation (hereafter "Russia") started the invasion of Ukraine.

The Danish society is fully engaged in the energy transition through broad political agreements on energy and climate, which guide policy making and public-private partnerships. Denmark has a robust energy and climate governance under the Ministry of Climate, Energy and Utilities and "the year wheel" of the Climate Act of 2020 to ensure annual policy actions and funding are geared towards emissions reductions. Under the Act, Denmark also publishes every year a global climate impact report, analysing the climate and carbon footprint of its consumption.

Transitioning towards climate neutrality

Since the IEA's last review in 2017, Denmark has considerably stepped up its energy and climate targets. Under the 2020 Climate Act, the government is legally bound to reduce greenhouse gas (GHG) emissions by 50-54% in 2025 and by 70% towards 2030 from 1990 levels.

In 2022, the new coalition government proposed to bring forward the climate neutrality target to 2045 and target a 110% emissions reduction by 2050. The goals have not yet been adopted in the Climate Act, but the Act is expected to be revised.

Reducing GHG emissions by 70% by 2030 requires achieving in only seven years what was achieved over the past 30 years. In 2023, the Danish Energy Agency's (DEA) Climate Status Outlook warns of a gap towards the 2030 targets based on existing measures and policies. Additional measures will be needed to reach the targets, notably in transport, agriculture and industry. The government is pursuing a green tax reform in these sectors and aims to phase in a carbon tax from 2025 onwards. This is critical given the fact that in 2021, only around 45% of Denmark's emissions were covered by an effective carbon rate (by either carbon or fuel tax), according to the OECD *Effective Carbon Rates* analysis.

Thanks to the integration with Nordic and European continental power systems, Denmark is well placed to advance the decarbonisation of its economy and become a major exporter. Denmark's deployment targets are impressive: by 2030, onshore wind and solar power generation are to quadruple. Offshore wind capacity is targeted to increase potentially sevenfold to 18 gigawatts (GW) by 2030 and 35 GW by 2050, from today's 2.3 GW. Under the Power-to-X (PtX) Strategy of 2021, Denmark is targeting 4-6 GW of electrolysis capacity by 2030.

Moreover, at a regional level, Denmark supports the deployment of 20 GW in the Baltic Sea for 2030 and together with eight European countries in the North Sea has signed up to the joint pledge of 120 GW of offshore wind capacity by 2030 and at least 300 GW by 2050.

Denmark is a regional hub for shipping and aviation and together with the industrial clusters in the North Sea region, a centre of demand for low-emission hydrogen, e-fuels as well as carbon capture, utilisation and storage (CCUS). Within a record time of three years, Denmark has created framework conditions and rules for CCS, completed a first CCS tender and allocated a first CO_2 storage licence. The PtX Taskforce is supporting the roll-out of the hydrogen and low-emission fuels strategy with more than 30 PtX projects and actions underway.

For industry to go ahead with the business and export opportunities at a fast pace, the government needs to support the framework conditions and lower investment risks for industry for infrastructure roll-out for grids, CO_2 and hydrogen by evaluating supply chain risks, supporting bilateral agreements and the development of European Union (EU) rules. These rules include the Carbon Border Adjustment Mechanism, the certification of hydrogen and a framework for CO_2 transportation and storage, and EU rules for negative emissions.

With such ambitious projects, system integration challenges may increase in the Danish system, depending on the renewable expansion in the region. The creation of a regional green infrastructure master plan is critical for business to make investments, allowing for demand and supply areas and future trade connections to be identified. Denmark has decided that the state-owned transmission system operator Energinet and gas distribution company Evida will own and operate the future hydrogen pipeline infrastructure. Progress is underway with bilateral agreements. Denmark and Germany will build a hydrogen pipeline by 2028 and agreed to co-operate on wind offshore and CCUS collaboration projects at the Ostend Summit in May 2023.

The export orientation of Denmark's clean energy technology development should be incorporated in the coming years into the country's global climate diplomacy to form industrial net zero partnerships with partners across the globe.

Implementing a people-centred energy transition

The government's policy imperatives are to ensure the targets are implemented in the most cost-effective and socially balanced manner while avoiding carbon leakage, as enshrined in the Climate Act's principles. This will require improved tracking, readability and visibility of the targets, which are set out across a wide range of agreements, and an implementation partnership with municipalities and businesses.

Changes in the support scheme, the introduction of locational grid charges, the slow pace of grid investment as well as onshore permitting barriers have impacted onshore renewable investment in the past few years. The IEA expects the expansion to pick up again in 2024 and 2025 thanks to accelerated deployment of solar PV. DEA is forecasting a 117% share of variable renewables in electricity by 2030. The IEA expects Denmark's total renewable electricity capacity to almost double over the 2022-2027 period thanks to offshore wind additions in 2023-2024 at Vesterhav Sud and Nord and Thor (1 GW by 2027-2028). Taking into account the Bornholm Energy Island and additions from solar PV, growth could be even higher.

While Denmark has a world-class permitting system in place for offshore wind, no such support exists onshore. For the decarbonisation of heat, municipal planning is in place but a greater degree for co-ordination is required to phase out old oil and gas boilers in the coming years. National screening of areas suited for onshore wind turbines, solar PV and PtX are proposed to achieve the goal of quadrupling onshore renewable energy by 2030. The government wants to support and accelerate the municipalities' planning process by establishing energy parks. To do so effectively, it could review Europe's best practices for permitting, including one-stop shop registrations onshore for renewables, with digitalisation and designated areas as well as overriding public interest obligations.

The National Energy Crisis Team (NEKST) could become an important co-ordination body across all levels of government to identify barriers, enable an energy system approach, prepare reforms and speed up the implementation of critical measures to achieve the near-term targets for 2025 and 2030. Launched in 2022, the NEKST initiative would be effective with a clear mandate and terms of reference and a timetable for delivering the recommendations. NEKST could be tasked with the national co-ordination of an accelerated roll-out of renewable energy and co-ordinated actions across local actors.

To reduce the impact of the associated structural change in its regions, the government aims to locate energy projects in affected regions. As part of Denmark's decision to phase out oil and gas production in the North Sea, the government adopted an aid package to ensure local jobs for the existing skillset of oil and gas workers through CCUS and electrification projects.

At a global level, Prime Minister Mette Frederiksen headed the IEA high-level Global Commission on People-Centred Transitions, which provided a set of recommendations on how to ensure people are at the centre of the global energy transition.

Maintaining energy security during the transition

In the context of Russia's invasion of Ukraine and the energy crisis in 2022, Denmark's policy focus has reinstated the urgent need to reduce dependency on fossil fuels. While coal and gas use have decreased, oil still makes up a third of TES and the share has not decreased in the last decade.

To address the energy crisis, in June 2022, the government reached a broad agreement that supports 100% biomethane in heating by 2030. Denmark had already decided to phase out natural gas use by switching to district heating and heat pumps. Denmark is among the global leaders in biomethane, with around 70 large producers that inject into the gas distribution network. In 2023, the DEA expects gas consumption to consist of 39% biomethane and 61% of natural gas. Increasing the energy efficiency of the transport

system, raising targets for biofuels and electric vehicles (EVs) should all be part of an energy security road map for the medium term.

Such an energy security road map could help Denmark navigate a secure energy transition, considering both new and traditional fuels and Denmark's role in the regional context as an oil and gas producer.

Denmark's vulnerability and reliance on fossil fuel and large bioenergy imports was brought into sharp relief with the crisis. Denmark relied on Russian imports for 44% of its coal supply and 15% of its oil supply prior to the start of Russia's war on Ukraine, and substantial use of biomass in co-generation power plants that are used as a source of heat for 70% of the district heating system. Approximately 75% of biomass is imported, primarily from Baltic states (especially Latvia), as well as other international sources. Wood pellets can be stored but storage of woodchips is more difficult as the quality of the chips degrades over time. The temporary halt of domestic production at the Tyra field due to modernisation works meant that Danish oil and gas production dropped and imports increased at a time of global market constraints.

Denmark can learn from the energy crisis with a view to prepare for the winter 2023-24, which will require a continuous focus on energy savings, renewables deployment, maximised energy production and the scaling up of clean energy investment.

One lesson learnt is that demand-side flexibility can be enabled. In 2022, Danish households reduced gas, electricity and district heat consumption by around 20%, based on price signals. In 2023, consumption levels remain below historic averages, showing that the crisis action is potentially leading to real behaviour change. The government should ensure the economic and energy system benefits are long-lasting by accelerating the roll-out of biogas, peak shaving through demand response, increasing digitalisation, implementing strategies for smart consumer behaviour and increasing the flexibility of the power system.

Energy efficiency alongside digitalisation can be an enabler of energy system integration to support efficient investment in grids and aligning supply and demand and greater system flexibility. It can also boost affordability. In 2022, Denmark had one of the highest average household annual energy expenditures after the United States and the Netherlands. Between 2019 and 2022, Denmark's household energy expenditure increased by 49% because of higher energy prices. A new vision and strategy for energy efficiency would be an important plank for government action on energy security.

Key recommendations

The government of Denmark should:

- Scale up actions to increase the delivery of policies and measures towards its 2025-2030 energy and climate goals by lifting barriers and accelerating the implementation of targets and political agreements already made, building on the close dialogue with local communities and energy sector stakeholders.
- Prepare for winter 2023-2024 with actions focused on energy savings, accelerating the deployment of renewables and maximising domestic energy production.

- Design an energy security road map for Denmark to address traditional and emerging security challenges from extreme weather events, cybersecurity and supply chain risks based on a national risk assessment, including biomass sourcing and stocks.
- Support investment and create the necessary framework conditions for future energy system needs and energy sector integration through the design of an export-oriented clean energy supply chain strategy and international industrial net zero partnerships, notably in the North and Baltic Seas.
- Work with neighbouring governments, regulators and system operators to prepare a green infrastructure masterplan which includes major regional projects to progress Denmark's ambition for green power, CO_2 and hydrogen.

1. General energy policy

Key data (2022)

Total energy supply: 649 PJ; -10% since 2011

Total energy supply by source: oil 37%, bioenergy and waste 33%, solar 12.2%, natural gas 9.3%, coal 6.9%, electricity imports 0.8%, heat 0.4%

Energy intensity per capita (TES/capita) (2021): 116 GJ/capita (IEA average: 166.7 GJ/capita); -14% since 2011

Energy intensity per GDP (TES/GDP*) (2021): 2.16 MJ per 2015 USD PPP (IEA average at 3.7 MJ per USD); -24% change since 2011

Total final energy consumption (2021): 559 PJ; -4.4% since 2011

Total final energy consumption by sector (2021): buildings (47%), transport (30%) and industry (25%)

* Gross domestic product in 2015 prices and purchasing power parity (PPP).

Source: IEA (2023), World Energy Balances.

Country overview

Denmark is a Northern European country bordering the Baltic Sea and the North Sea. Most of the country is located on the peninsula Jutland (north of Germany) with the remainder made up of 406 islands, including Sjaelland, Fyn and Bornholm. Its territory expands over 43 000 km² and is composed of low to gently rolling plains.

Denmark's population has been growing and reached 5.9 million in 2022, 5% higher than in 2011. Eighty-eight per cent of the Danish population lives in urban areas. The capital, Copenhagen, with 1 million inhabitants, is the most populous city. Other major cities include Aarhus, Odense and Aalborg. The national currency is the Danish krone (DKK, exchange rate of DKK 7.083 per USD 1 on 1 October 2023 or EUR 0.13 for DKK 1).

Economy

In 2022, Denmark's gross domestic product (GDP) per capita was USD 74 859, above the OECD average of USD 53 957. The services sector accounted for 66% of Danish GDP, with industry and manufacturing accounting for 33% and the primary sector for 1%. The employment rate in the second quarter of 2022 was 77% (of the working age population), which is the tenth highest among OECD countries. The Covid-19 pandemic caused Denmark's GDP to fall by 2% in 2020, but it rebounded by 5% in 2021. GDP growth is

projected to slow to 0.7% in 2023, before recovering to 1.4% in 2024; inflation is expected to decline from 4.9% in 2023 to 3.2% in 2024.

Political structure and energy

Denmark is a constitutional monarchy with a parliamentary democracy; the parliament is called the Folketing. The official head of state is the Danish Queen, who has a ceremonial role. The most recent elections were held in November 2022. The new Danish government was announced on 15 December 2022. Prime Minister Mette Frederiksen, in office since 27 June 2019, continues her tenure with a wider coalition. The government is now comprised of the Social Democrats as well as the centre-right parties – the Liberals (Venstre) and the newly formed Moderates. Lars Aagaard is the Minister of Climate, Energy and Utilities. The new government created a ministerial portfolio for international climate engagement. Dan Jørgensen serves as Minister for Development Cooperation and Minister for Global Climate Policy.

Institutional landscape for energy and climate

Denmark has a robust institutional structure which integrates energy and climate matters under the Danish Ministry of Climate, Energy and Utilities and its agencies and associated independent bodies. Ministers of relevant portfolios meet every week under the national Committee for Green Transition, whose secretariat is the Ministry of Climate, Energy and Utilities. There are also regional green co-operation committees.

Created in 2014, the Ministry of Climate, Energy and Utilities is made up of the central Department and consists of five authorities and three bodies that are independent organisations under the auspices of the ministry: the Geological Survey of Denmark and Greenland, the Danish Meteorological Institute, the DEA, the Danish Geodata Agency, and the Danish Agency for Data Supply and Infrastructure, as well as the associated independent bodies, the Danish Utility Regulator, Energinet and the Danish Climate Council (see Figure 1.1).

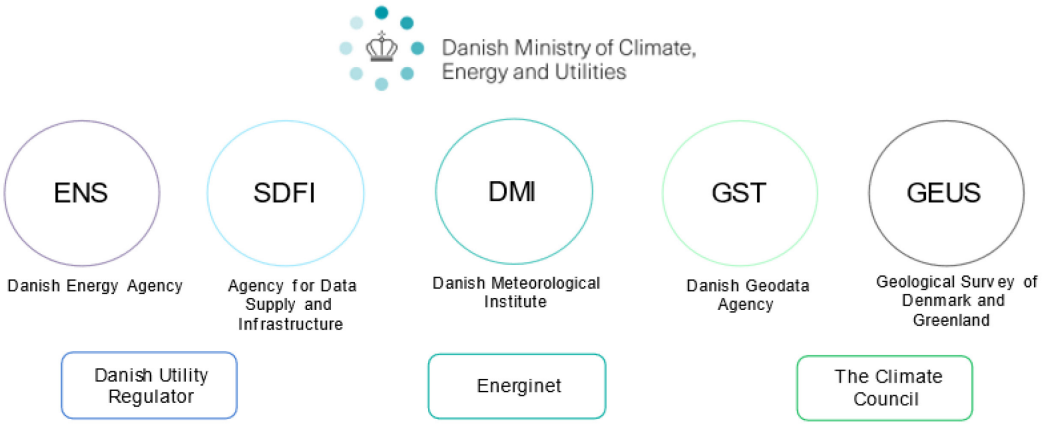
The Danish Climate Council is an independent body of experts that regularly reviews Danish climate policies with regard to their stringency and cost-effectiveness.

The DEA oversees energy production, supply and consumption as well as climate change mitigation. It supports the economic optimisation of utilities (energy includes water and waste). The agency is also responsible for user conditions, supply obligation, statistics, water supply and waste management.

Energinet is the independent but state-owned company that owns Denmark's electric and natural gas grid. Its primary responsibility is to control and maintain the national electricity transmission grid, the national gas distribution grid and the supply of natural gas.

The Danish Utility Regulator is responsible for the Danish markets for electricity, natural gas and district heating. In the electricity market, the regulation focuses on the network companies. The authority sets the allowed price for electricity companies with an obligation to supply. In the natural gas market, the regulation also focuses on gas distribution network operators. The Danish Utility Regulator sets the price for natural gas supplied by the natural gas companies with an obligation to supply.

Figure 1.1. The Danish energy and climate policy governance

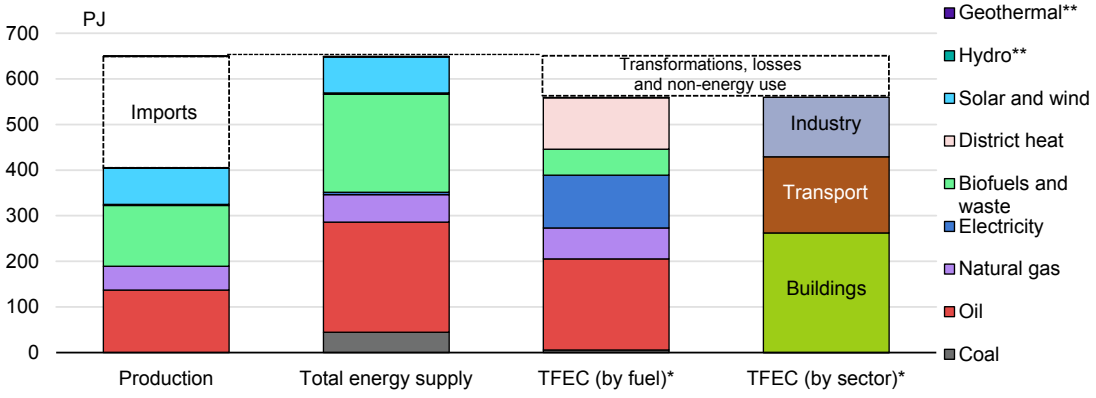


Source: Reproduced and adapted from Denmark, Ministry of Climate (2023), Energy and Utilities.

Energy supply and demand

In 2022, Denmark's domestic production of energy secured over 60% of TES, with imported fossil fuels and biomass covering the remainder (Figure 1.2).

Figure 1.2 Overview of energy production, supply and demand in Denmark, 2022



* TFEC (total final energy consumption) data refer to 2021.

** Hydro and geothermal represented 0.07 PJ and 0.08 PJ in production, respectively.

Source: IEA (2023), World Energy Balances.

In 2022, oil was the largest source of energy production (137 petajoules [PJ]), followed by bioenergy and waste (133 PJ), solar and wind (79 PJ), and natural gas (52 PJ). Lower amounts of energy are also produced from hydro (0.1 PJ). Over the past decade, oil and gas production have dropped by 68% and 76%, respectively. Conversely, bioenergy and waste on one side, and solar and wind on the other, increased by 33% and 107%, respectively.

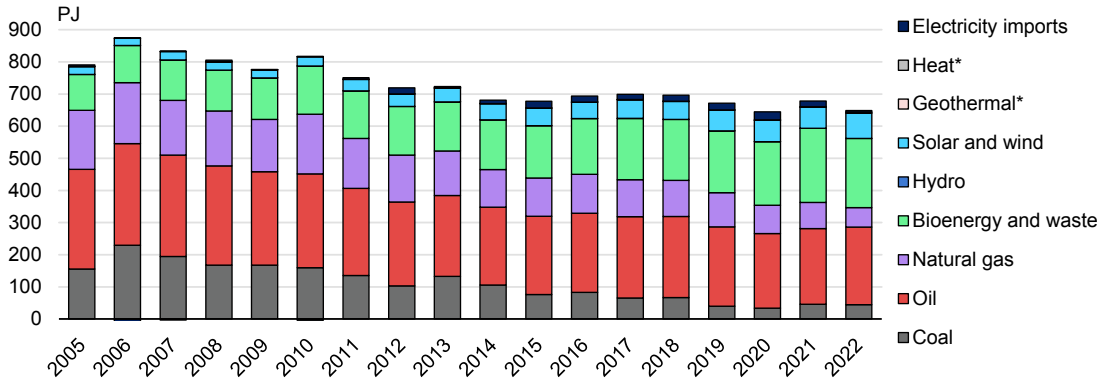
Total energy supply

Denmark's TES has decreased by 18%, from 812 PJ in 2010 to 671 PJ in 2019 (Figure 1.3). In 2020, TES dropped to 644 PJ, driven by the Covid-19 pandemic, but rebounded in 2021 and was 678 PJ in 2022, above the 2019 level.

The share of fossil fuels in Denmark's energy supply has been falling consistently over the past two decades, from 75% in 2011 to 53% in 2022 and is today much lower than the IEA average of 79%. But oil still dominates TES and its share remained stable at 36%. Thanks to the rapid growth of wind power and biogas/biomass, the share of coal decreased from 18% in 2011 to 6.9% in 2022 and the share of gas is down from 21% to 9.3%. Over the period, the share of bioenergy and waste grew from 20% to 34% while the share of variable renewables (mainly wind and some solar PV) in TES grew from 5% to 9%.

Over the past 15 years, Denmark has mainly been a net importer of electricity, with some years as a net exporter (2006, 2007 and 2010). However, in the coming years, it is expected to turn into a net exporter of electricity.

Figure 1.3 Total energy supply by source in Denmark, 2005-2022



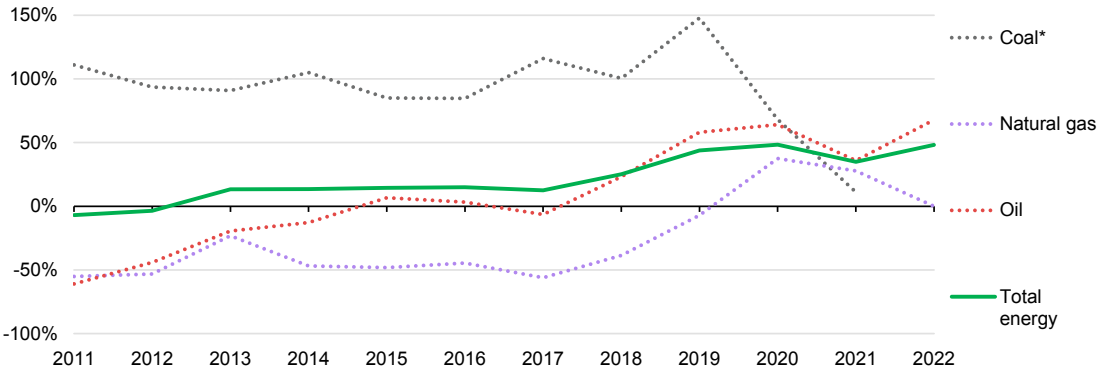
* Geothermal and heat are not visible on this scale.

Source: IEA (2023), World Energy Balances.

With declining domestic oil and gas production, Denmark's import dependence has increased in recent years (Figure 1.4). In 2019, it became a net importer of natural gas with the redevelopment of the Tyra offshore complex. It has already been a net importer of crude oil since 2017. In line with the DEA's projected oil and gas production, Denmark is set to remain an oil importer for the coming decades. The return of the Tyra field in the winter of 2023-24 would ensure the country to be a net exporter of natural gas.

Prior to Russia's invasion of Ukraine, Denmark relied on imports from Russia to cover total energy supply – 44% for coal and 15% for oil as well as a large share of biomass. Since their peak in 2019, coal imports have declined rapidly with the phase-out of coal use in electricity and heat and a switch to natural gas and bioenergy. However, coal use saw a slight increase from 2021 to 2022 due to the energy crisis amid unavailable domestic gas production in Denmark.

Figure 1.4 Import dependence (net imports as a share of total energy supply) in Denmark, 2011-2022



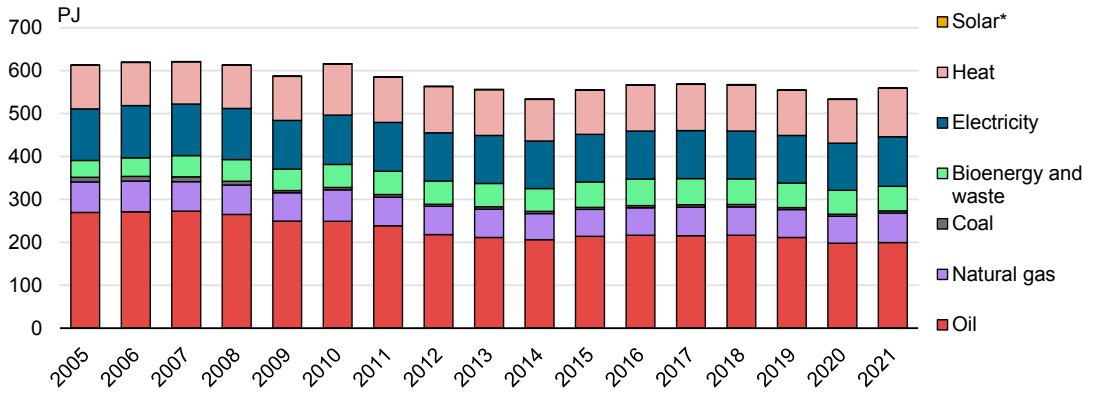
* Coal data are only available until 2021.

Source: IEA (2023), World Energy Balances.

Energy demand

Total final energy consumption (TFEC) has decreased, from 616 PJ in 2010 to 554 PJ in 2019; it then fell by 3% to 533 PJ in 2020 amid the Covid-19 pandemic (Figure 1.5). Denmark's energy demand is dependent on fossil fuels, with oil and natural gas covering 36% and 12% of the country's TFEC, respectively in 2021 The share of coal was very low (1%). Bioenergy and waste cover 10% of TFEC. Electricity accounts for 21%, followed by district heat at 20%.

Figure 1.5 Total final energy consumption by source in Denmark, 2005-2021



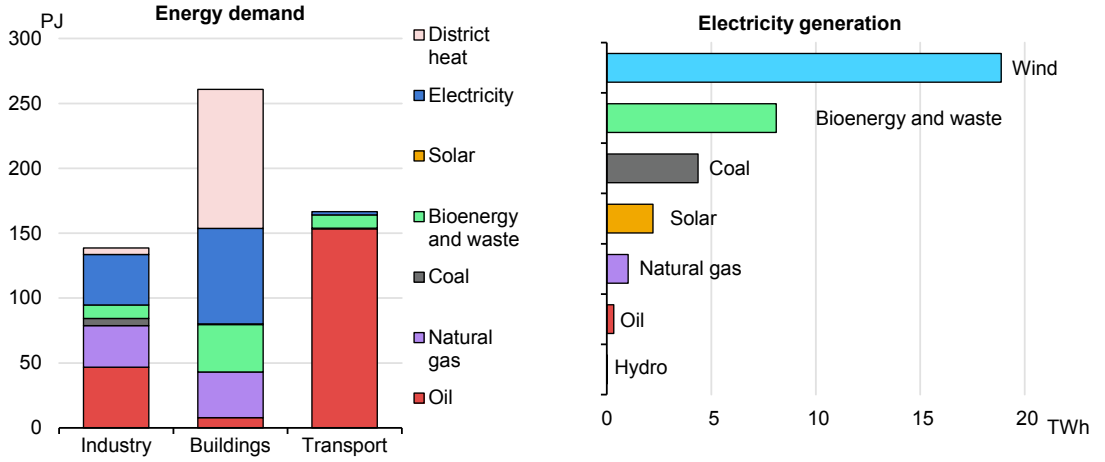
* Solar is too small to be visible on this scale.

Source: IEA (2023), World Energy Balances.

Buildings made up the lion's share of consumption (45%, compared to the IEA average of 33%), followed by transport (30%) and industry (25%). Electricity accounts for 29% of demand in the buildings sector and 28% in the industry sector. District heating plays a very important role in buildings' energy consumption. As in most IEA member countries, Denmark's transport sector remains almost completely reliant on oil (92% of transport TFEC in 2021). Bioenergy is used in buildings (14%), industry (8%) and transport (6%). Natural gas is used mainly in the industry sector (22%) and in buildings (11%). Coal is

consumed in the industry sector (3%). Electricity generation is dominated by renewables, with the highest share of wind (54%) among IEA member countries in 2022. The second source of electricity generation was bioenergy and waste (23%), followed by coal (13%), solar (4.1%), natural gas (4.1%), oil (0.9%) and hydro (0.1%).

Figure 1.6 Energy demand in 2021 and electricity generation by fuel in 2022



Source: IEA (2023), World Energy Balances.

Denmark's energy and climate strategy

Denmark's energy and climate strategy is shaped by a broad and sustained political commitment to the country's energy transition, supported by sectoral energy and climate agreements concluded in partnership with Danish business and energy sector stakeholders.

Denmark makes international climate and energy diplomacy a key priority, including by sharing its best practices on energy efficiency, energy system planning and technology expertise internationally.

The government has committed to end fossil fuel production. In 2020, a broad majority in the Danish parliament reached an agreement on the future of fossil fuel (oil/gas) extraction in the North Sea, leading to a final phase-out date by 2050 and to the cancellation of the ongoing eighth licensing round and future rounds (except for small existing fields).

The 2020 Climate Act implements a political agreement from 2019, setting a legally binding target of reducing GHG emissions by 70% in 2030 from 1990 levels, with the aim of making Denmark a climate-neutral society by 2050. In 2022, the current government has proposed to advance the goal of climate neutrality to 2045 and to achieve a 110% emissions reduction by 2050 compared to 1990.

Since Russia's invasion of Ukraine, Denmark has reaffirmed its focus on phasing out fossil fuels and accelerating renewable energy deployment. With a view to bolster Denmark's energy security and reduce electricity and heating prices for Danish households, the Agreement on Green Power and Heat (25 June 2022) sets the political ambition of reaching 100% green gas use across all sectors and ending the use of natural gas in

household heating at the latest by 2035. Under the Agreement, Denmark aims to quadruple onshore wind and solar PV generation by 2030 (no split by technology is indicated), which translates into a production of 50 terawatt hours (TWh) in 2030.

Offshore wind is targeted to increase potentially sevenfold to 18 GW by 2030 and a minimum of 35 GW by 2050. Denmark has set a target to build up to 4-6 GW of electrolysis capacity by 2030 as part of the 2021 PtX Strategy.

Under the Agreement on Winter Help (*A Helping Hand*, 23 September 2022), the government decided on the temporary voluntary freeze of electricity and gas prices, a temporary relief of the ordinary electricity bill, an electricity price rebate for installing a heat pump, a better supply of wood pellets, increased subsidies for disconnecting from the natural gas grid and the roll-out of district heating networks.

Danish government's political framework (2022)

In December 2022, the coalition presented its government political framework as an agreement between the three winning parties of the 2022 elections. The government seeks to maintain Denmark's role as a green pioneer in setting and meeting ambitious climate targets and global climate action, inspiring other countries to follow.

Ambitious climate action

- Meet the climate targets for 2025 and 2030 with an emissions reduction of 50-54% and 70% from 1990 levels, respectively.
- Advance the goal of climate neutrality to 2045 and of achieving a 110% emissions reduction by 2050 compared to 1990 levels, requiring stronger contributions from negative emissions, notably CCUS.
- Meet the agricultural and forestry sector's emissions reduction target (as set out in the Agreement on Agriculture from 2021) as a key enabler for meeting the overall 2030 target.
- Prepare an ambitious GHG emissions reduction target for 2035 and assess the need for an upward revision of the 2030 target.
- Set a target for Denmark's international climate impact, resulting from the export of energy technology and services, based on technical analysis carried out in co-operation with the Danish business community.

Greener transport

- Examine an increased ambition for the number of clean EVs in Denmark based on the review of the Road Transport Agreement.
- Continue to promote zero emission vehicles based on the pool for fuel infrastructure for heavy road transport from the Infrastructure Compromise, notably the conversion of fleets and the installation of charging stations.
- Create one green domestic route by 2025 and fully decarbonise domestic aviation by 2030, financed by the passenger tax on air travel (averaging DKK 100).
- Accelerate the transformation of heavy-duty transport, maritime transport and aviation, including by promoting electrification and low-emission fuels.

Expanding renewable energy and phasing out fossil fuels

- Streamline procedures and clarify the division of tasks between authorities, regions and municipalities to increase efficiency and shorten deployment times for renewable energy.

- Boost co-operation across the North Sea and Baltic Sea regions for a faster and more co-ordinated development of the infrastructure needed to promote offshore wind.
- Transition away from fossil fuels in heating, weaning off as many households' individual gas and oil burners as quickly as possible. Increase public funding to compensate for the fee charged for disconnecting and removing the gas meter.
- Increase the production of biogas so that Denmark can displace Russian gas more quickly, including by bringing forward agreed tenders.
- Strengthen the focus on energy efficiency of residential, commercial and public buildings.
- Launch an electricity grid extension plan and identify measures to support timely and efficient investments in the electricity grid. Amend the grid regulation to support power system flexibility.

Danish clean energy value chains

Denmark has promoted an accelerated offshore wind development and today leads globally with strong industrial players. Taking its leadership to the next level, Denmark is creating dedicated energy islands and adopted ambitious targets for PtX, focusing on the production of hydrogen and CCUS.

The country has a large CO_2 storage potential within saline aquifer structures and depleted oil and gas fields. It has the strong expertise to deploy new infrastructure and integrate complex chains from source to storage. Northern Europe has concentrated CO_2 emissions from industry and manufacturing, which can build a large-scale competitive cross-border CCS value chain by 2030. Denmark aims at becoming a European hub for CO_2 storage. Agreements with Flanders and Belgium were made for the geological sequestration of CO_2.

Denmark's CCS approach is based on three key strategies: 1) the Climate Agreement for Energy and Industry (2020); 2) the Agreement on a Roadmap for Capture, Transport and Storage of CO_2 (2021); and 3) the Agreement on the Framework for CO_2 Storage in Denmark (2022). The Climate Agreement for Energy and Industry identifies CCS (among other technologies) as an enabler for achieving the Danish climate goals. These also form the basis of Denmark's CCUS funding schemes.

In 2021, Denmark presented the PtX Strategy as a key enabler for its climate targets, industrial development and international export ambitions. Denmark is creating the regulatory framework and developing the infrastructure to enable the industry to operate on market terms in the long run, thus improving the interaction between PtX and the Danish energy system with a view to export-related PtX products and technologies.

Denmark has a strong foundation for full energy sector integration, thanks to the integration of electricity and heat production, thermal storage from the district heating system, and ample interconnections, which all provide cost-efficient flexibility solutions for the power system. With growing electrification and the development of PtX, the system can move to the next level of energy sector integration (see Chapter 10).

Box 1.1 IEA recommendations on global clean technology manufacturing

Since late 2022, the estimated output by 2030 from existing and announced manufacturing capacity for solar photovoltaics has increased by 60%, for batteries by 25% and for electrolysers by 20%, propelled by policy support and growing interest from investors. The majority of announced manufacturing projects across most key clean energy technologies do not have committed investments. In Europe, around 10% of the announced battery factories are under construction whereas only 2% are for electrolysers. However, such manufacturing facilities can be brought online with relatively short lead times – one to three years on average – meaning that deployment can rapidly scale up if support is maintained. Manufacturing projects that have been announced but not firmly committed may end up being relocated to different countries in response to policy shifts and market developments. In an era of great change, project developers and investors are on the lookout for supportive policies that could give them the edge in different markets. Since the beginning of the decade, several major economies have introduced new policies to boost domestic clean technology manufacturing. Examples from the past year alone include the Inflation Reduction Act in the United States, the Net Zero Industry Act in the European Union and various milestones in Japan's Green Transformation programme.

Policy frameworks are not the only factor influencing change in technology manufacturing. Each country will need to carefully consider its own individual circumstances to assess where in the supply chain to specialise domestically, and where it might be more effective to establish strategic partnerships or to make direct investments in other countries. One of the major differentiators in the competitiveness of energy-intensive industry sectors in different countries, and thus their attractiveness for manufacturers, is the cost of energy.

IEA recommendations focus on actions that require international co-operation:

- Co-ordinate efforts across supply chains to determine risks posed to different elements that could delay or disrupt deployment and resilience in the face of potential market shocks.
- Identify and build strategic partnerships, both within the G7 and beyond. For most countries, it is not realistic to effectively compete in all supply chain steps, nor in all supply chains.
- Facilitate investment in emerging markets and developing economies with pooled investments, knowledge-sharing and other strategies to reduce risks – and consequently, the costs of financing – for capital-intensive components of supply chains.
- Develop a platform to inform the process of identifying strategic partnerships for manufacturing.
- Share best practices and domestic experience on measures relevant to accelerating progress in clean technology manufacturing, such as creating favourable investment conditions, accelerating permitting and stockpiling of input materials and components. "How-to-guides" for developing industrial strategies could be a vehicle for disseminating such efforts among countries.
- Promote manufacturing technologies and strategies to enhance resource efficiency, thereby increasing the resilience of clean technology supply chains.

Source: IEA (2023), State of Clean Technology Manufacturing, Special Briefing for the G7.

Denmark's people-centred energy strategy

In 2021, Danish Prime Minister Mette Frederiksen headed the IEA high-level Global Commission on People-Centred Transitions, which provided a set of recommendations on how to ensure people are at the centre of the global energy transition (Figure 1.7).

As part of Denmark's decision to phase out oil and gas production in the North Sea by 2050, the government adopted an aid package to ensure local jobs for the existing skillset of oil and gas workers through CCUS and electrification projects.

To support an inclusive transition, Denmark established a Citizens' Assembly in 2020. The 2022 Coalition Agreement also announced plans to establish the "Together for Climate" partnership to support accelerated action across government, local and regional authorities, civil society, and business, with an emphasis on the citizen.

Table 1.1 Principles for just energy transitions

DECENT JOBS AND WORKER PROTECTION	
1	Design transitions to maximise the creation of decent jobs.
2	Develop tailored government support for communities and workers and focus on skills and training.
3	Use social dialogue, robust stakeholder and policy co-ordination to deliver better outcomes
SOCIAL AND ECONOMIC DEVELOPMENT	
4	Ensure that policies enhance social and economic development, and improve quality of life for all.
5	Prioritise universal clean energy access and eliminating of energy poverty.
6	Maintain and enhance energy security, affordability and resilience
EQUITY, SOCIAL INCLUSION AND FAIRNESS	
7	Incorporate gender, equality and social inclusion considerations in all policies
8	Ensure the fair distribution of clean energy benefits and avoid the risk of disproportionate negative impacts on vulnerable populations.
6	Integrate the voices of younger generations in decision making
PEOPLE AS ACTIVE PARTICIPANTS	
7	Involve the public through participation and communication.
8	Use insights from behavioural science to design effective behaviour change policies
6	Enhance impact through international collaboration and the exchange of best practices

Source: IEA (2021), Recommendations of the Global Commission on People-Centred Clean Energy Transitions.

The Danish government created NEKST to speed up energy infrastructure deployment in Denmark. The government's political framework (2022) announced that NEKST will, with the involvement of relevant societal actors, ensure national co-ordination of district heating deployment, identify barriers to the agreed ambitions for scaling up solar and on and offshore wind, and recommend possible actions to accelerate deployment as well as support the expansion of the electricity grid.

Denmark has seen strong local commitment to and citizen involvement in the energy transition. For example, the local municipality of the island of Samsø fully transformed its energy system from fossil fuels to renewable energy, becoming carbon negative with 100% local ownership of renewable energy investments providing significant local socio-economic benefits from the energy transition. To share its expertise, the Samsø Energy Academy was created with a mandate from the municipality to support capacity building on community development and international co-operation in Denmark, Europe and beyond. The Academy also participates in co-operation and knowledge exchange programmes, provides advice on sustainable community development, and organises on Samsø study visits, workshops and leadership programmes to inspire local leaders, stakeholders and policy makers from around the world.

Assessment

Since the IEA's last review in 2017, Denmark has significantly stepped up its leadership in the energy transition, targeting climate neutrality by 2045 and a stronger stance on negative emissions, in advance of the forthcoming discussion on the revision of the EU Climate Law and the 2040 EU emissions reduction target.

Denmark has very ambitious decarbonisation targets, funding programmes, and several broad political agreements on energy and climate, which guide policy development and public-private partnerships. Denmark has a robust institutional structure for energy and climate.

Under the new coalition government's policy framework, Denmark is committed to meeting its emissions reductions targets of 50-54% by 2025 and 70% to 2030 from 1990 levels, as legislated under the Climate Act, while advancing the goal of climate neutrality from 2050 to 2045 and aiming at a 110% reduction by 2050. Reaching the climate targets in the most cost-effective and socially balanced manner while avoiding carbon leakage have been the policy imperatives and guiding principles of the Danish Climate Act. There is strong consensus in the Danish society on the energy transition and decisions are based on scientific evidence and socio-economic analysis.

Since 2020, a wide range of broad political agreements have set out many new targets, including more ambitious ones since Russia's invasion of Ukraine. However, the government needs to improve the readability and visibility of the targets and track progress. Going forward, the government should focus on implementing the agreed targets for a more secure and affordable transition while supporting investment and promoting business opportunities and Danish technology leadership.

Implementing Denmark's energy and climate targets will require a continuous strong partnership between municipalities and business as well as citizens. The NEKST initiative is important in this context to ensure the implementation of the Danish climate and energy goals with support to local communities. By giving NEKST a clear mandate and terms of reference with a timetable for delivering recommendations, it could be a critical co-ordination body across all levels of government to identify barriers, enable an energy system approach, prepare reforms and accelerate the implementation of critical measures to achieve the near-term targets for 2025 and 2030.

Thanks to the increased use of biomass and natural gas, the district heating sector has practically phased out coal. Overall, the share of fossil fuels in Denmark's total energy supply decreased from 75% in 2011 to 53% in 2022, compared to the IEA average of 79%. The share of coal dropped significantly from 18% to 7% and gas decreased from 21% to 9.3% in 2022. During the period, the share of bioenergy grew from 20% to 34% and variable renewables from 5% to 9%.

In the context of Russia's invasion of Ukraine, Denmark's growing reliance on fossil fuel imports was brought into sharp relief. Denmark's domestic production of energy covers 60% of total energy supply, amid works on the Tyra offshore complex; the country increasingly relies on imported fossil fuels to cover the remainder. In 2020, Denmark relied on Russian imports for 44% of its coal supply and 15% of its oil supply. As the winter 2023-24 approaches, the government needs to keep a close eye on energy security.

Securing Denmark's energy transition requires attention to both new and traditional fuels, including oil/gas production from ageing fields and biomass sourcing and supply. In June 2022, the government reached a broad agreement that supports a 100% ambition for green gas use by 2030 in the context of ending Russian fossil fuel imports as soon as possible. Denmark had already decided to phase out natural gas use by switching to district heating and heat pumps. The Agreement on Winter Help of September 2022 promoted a range of short-term tax and subsidy measures to reduce gas use and decarbonise the heating system. In the short term, Denmark can learn from the energy crisis with a view to preparing for the winter of 2023-24, which will require an even stronger focus on energy savings, renewables deployment, maximised energy production and the scaling up clean energy investment.

The new government's key priorities are greater electrification to enable progress on decarbonising transport, agriculture and industry. In 2021, wind was the first source of Danish electricity generation, covering almost half of total generation (49%), the highest share among IEA member countries. By 2030, renewable energy is expected to cover 100% of electricity and 55% of total final energy consumption, thus allowing the energy sector to become decarbonised.

Thanks to very low-carbon electricity of 90 grammes of carbon dioxide per kilowatt hour (g CO_2/kWh) in 2022, Denmark has an excellent starting point for the green industrial era and the energy system of the future with a strong export opportunity. The demand for low-emission hydrogen, e-fuels as well as CCUS will come from hard-to-abate industries located in the neighbourhood of Denmark, which is a hub for ports, shipping and aviation in the North Sea. Denmark envisages an accelerated offshore wind development, including by creating dedicated energy islands, and adopting ambitious targets for electrolysis and PtX, hydrogen, and CCUS. Within record time, Denmark has created framework conditions and rules for CCS, issued the first tender and is developing storage projects, including across borders.

Denmark's deployment targets are very impressive. These ambitions can form the basis of a clean energy supply chains, export-oriented industrial strategy. This aligns with the new EU Green Industrial Strategy and the EU Net Zero Industry Act.

In the Ostend Declaration of May 2023, nine European countries pledged to make the North Sea the largest "green energy power plant in the world", with a joint target of 120 GW of offshore wind capacity by 2030 and at least 300 GW by 2050. Denmark announced that

it will develop 6 GW of offshore wind capacity by 2030. In May 2023, it announced that the Danish government will be taking a 20% share in the four new offshore wind tenders.

The government should evaluate the supply chain risks and opportunities for technology and innovation in Denmark as well as refresh its strategy for green partnerships globally. In the light of its very ambitious offshore wind and hydrogen targets, Denmark needs to address supply chain risks and critical mineral availability. Building on the export orientation of its clean energy technology development, Denmark's global climate diplomacy has an opportunity to build new industrial net zero partnerships across the globe.

For industry to go ahead with the business and export opportunities at a fast pace, the government needs to support the framework conditions and lower investment risks for industry by supporting the cross-border trade/investment agreements and the development of needed EU rules. These rules include, for instance, the Carbon Border Adjustment Mechanism, certification, and a framework for CO_2 transportation and storage. Importantly, the government needs to ensure infrastructure is being rolled out, both for CO_2 and hydrogen, and the value of biogenic CO_2 is clarified as negative emissions under the 110% target.

To enable PtX, the government needs to settle the funding and delivery mechanism for pipeline infrastructure. State-owned Energinet supports the planning of hydrogen, electricity and gas networks. But it is limited in taking on major commercial risks stemming from the roll-out of infrastructure needed to connect industrial clusters across the region. The role of the existing gas grid and energy efficiency to reduce peak loads and ultimately grid investment should be consistently integrated into a new network planning approach, as the *ex ante* revenue model starts in 2023. An energy system plan for Denmark and a regional green infrastructure master plan would enable businesses to take investment decisions. It is welcome that the government and parliament decided that Energinet (transmission) and Evida (distribution) will own and operate future hydrogen pipeline infrastructure. It is important for the region to build the enabling infrastructure to ensure projects can reach final investment decision. As in the past with the Nordic Masterplan, Denmark could support regional efforts to identify key projects and advance their construction through partnership agreements. At the Ostend Summit, Denmark and Germany agreed to accelerate their co-operation on offshore wind and CCUS projects. In March 2023, they agreed to construct a land-based hydrogen pipeline by 2028, which would satisfy Denmark's industrial demand (of 90 TWh by 2030).

Recommendations

The government of Denmark should:

- Scale up actions to increase the delivery of policies and measures towards the 2025 and 2030 goals by lifting barriers and increasing the speed of implementation of agreed-upon targets and political agreements, building on close dialogue with local communities and energy sector stakeholders.
- Prepare for the winter of 2023-24 with actions focused on saving energy, accelerating renewable deployment and maximising domestic energy production.

- Support investment and create the necessary framework conditions for the future energy system needs and energy sector integration through the design of an export-oriented clean energy supply chain strategy and international industrial net zero partnerships, notably in the North and Baltic Seas.
- Work with neighbouring governments, regulators and system operators to prepare a green infrastructure masterplan to progress Denmark's ambition for green power, CO_2 and hydrogen. Identify prospective regional projects and plan necessary transport infrastructure. Make the most use of existing infrastructure when developing new projects; if new infrastructure has to be built, quickly decide on ownership and responsibilities.

2. Energy and climate change

Key data (2022)

GHG emissions with LULUCF (2021):* 48.0 Mt CO_2-eq; -35% since 2005, -39% since 1990

GHG emissions without LULUCF (2021):* 45.5 Mt CO_2-eq, -33% since 2005, -36% since 1990

Energy-related GHG emissions by fuel: 27.1 Mt CO_2-eq (oil 61%, natural gas 15%, coal 15%, other 9%)

Energy-related GHG emissions by sector (2021): transport 40%, industry 25%, electricity and heat generation 25%, buildings 10%

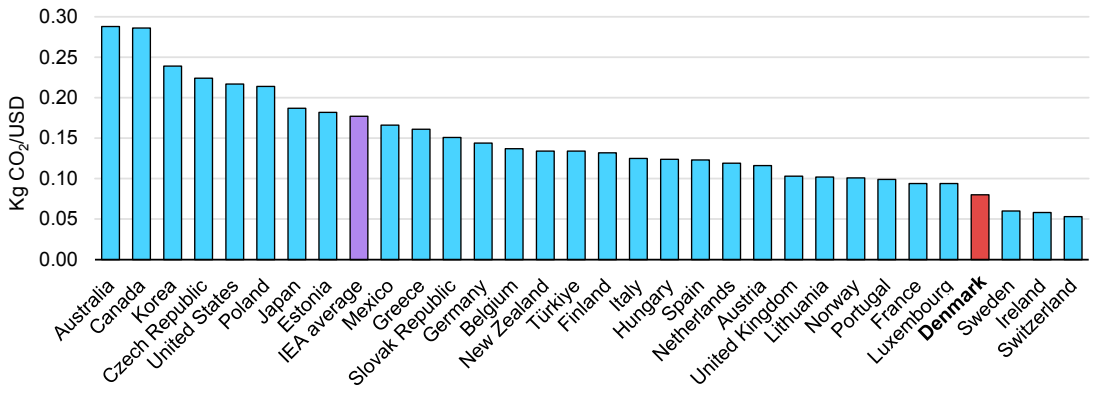
* Land use, land-use change and forestry.

Sources: IEA (2023) World Energy Balances; IEA (2023), Greenhouse Gas Emissions from Energy

Overview

Denmark has a low-emission economy. In 2022, its CO_2 emissions per unit of GDP were 0.08 kilogrammes of carbon dioxide per USD (kg CO_2/USD), which is the fourth lowest among IEA member countries, well below the IEA average of 0.18 kg CO_2/USD. Denmark's carbon intensity per capita is half the IEA average of 8.13 t CO_2/capita.

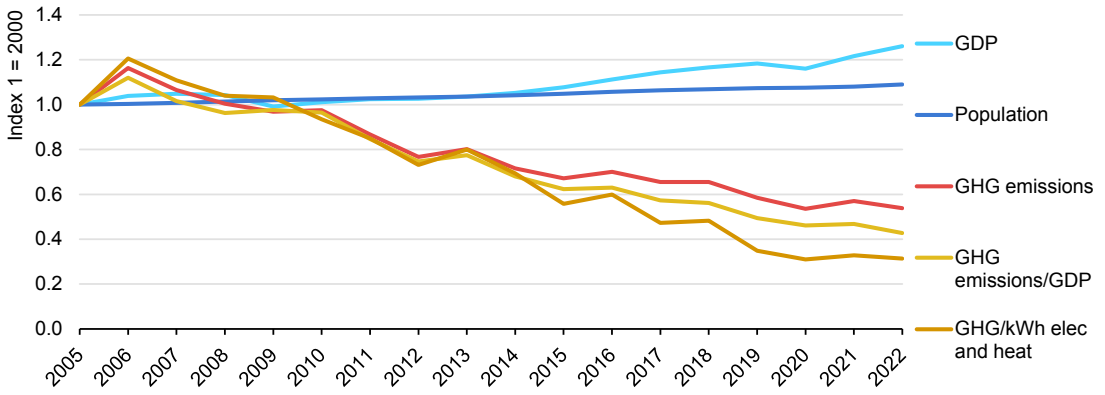
Figure 2.1 Carbon intensity of IEA countries, 2022



Source: IEA (2023), Greenhouse Gas Emissions from Energy.

Energy-related GHG emissions are decoupled from economic and population growth. Over the period 2005-22, Denmark's GDP increased by 26% while emissions dropped by 46% (Figure 2.2). Overall, the GHG intensity of Denmark's economy (GHG/GDP) and of its electricity production peaked in 2006 and have been declining since, compared to 2005 levels.

Figure 2.2 Energy-related greenhouse gas emissions and main drivers in Denmark, 2005-2022

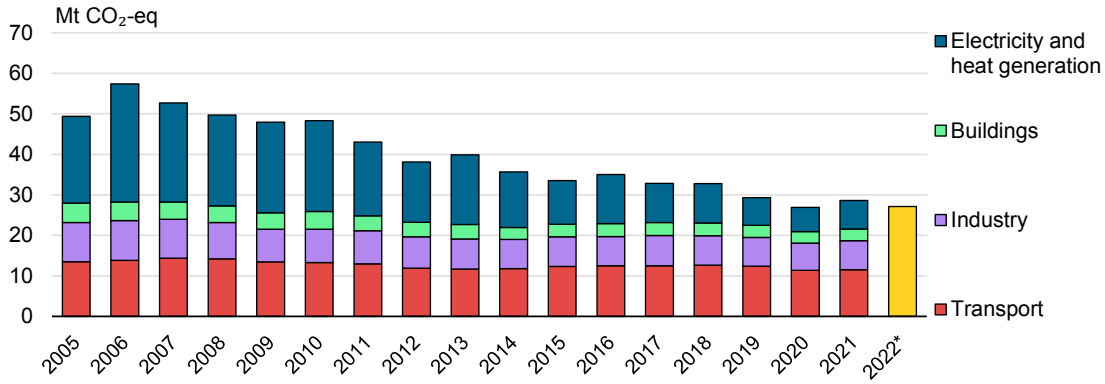


Sources: IEA (2023), World Energy Balances; IEA (2023), Greenhouse Gas Emissions from Energy.

Energy-related greenhouse gas emissions

In 2022, Denmark's energy-related GHG emissions were 27 Mt CO_2-eq, down from 2021, 45% below 2010 and 49% below 1990 levels. After peaking in 2006, energy-related emissions steadily decreased. They decreased further from 2019 to 2020 due to the Covid-19 pandemic, but briefly rebounded in 2021, as in many countries.

Figure 2.3 Energy-related greenhouse gas emissions by sector in Denmark, 2005-2022

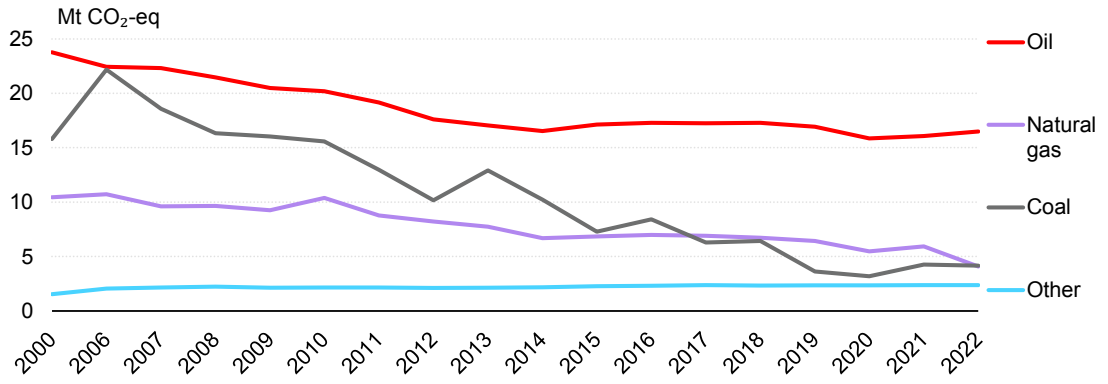


Notes: Breakdown by sector not available for 2022.
Source: IEA (2023) Greenhouse Gas Emissions from Energy.

The decrease since 2007 has been achieved thanks to almost 70% reduction in emissions from electricity and heat generation between 2005 and 2021, with a decreasing role of coal and gas and the rise of renewables (see Chapter 9). Emissions from the other sectors also decreased over the 2005-2021 period: -43% for buildings, -26% for industry and -15% for transport.

Domestic consumption of oil (mainly for the transport and industry sectors) remained responsible for 61% of emissions in 2022 and the absolute level has been overall constant over the last decade. Oil emissions increased in 2022 (up to 16.5 Mt CO_2-eq), with respect to 2021 and 2020, due to a rebound of economic activity (Figure 2.4). Since 2005, emissions from natural gas have fallen by 61%. Since the peak in emissions in 2006, coal emissions decreased by 72% over the 2005-22 period. Coal emissions rebounded in 2021 after the Covid-19 pandemic, to reach 4.2 Mt CO_2-eq in 2022. Waste emissions increased by 19% between 2005 and 2022, reaching 2.4 Mt CO_2-eq in 2022.

Figure 2.4 Energy-related greenhouse gas emissions by energy source in Denmark, 2005-2022



Source: IEA (2023) Greenhouse Gas Emissions from Energy.

Emissions reduction targets and policy

In 2022, Denmark raised its climate ambition. Under the Climate Act 2020, the country aims to cut GHG emissions by 50-54% by 2025 and by 70% by 2030, compared to 1990 levels. The new government coalition framework wants to reach climate neutrality by 2045 and achieve a 110% emissions reduction in 2050.

The 2030 target of reducing GHG emissions by 70% from 1990 translates into an effort of halving emissions (-35% compared to 1990), which requires a reduction in the next decade similar to that which was achieved over the past 30 years.

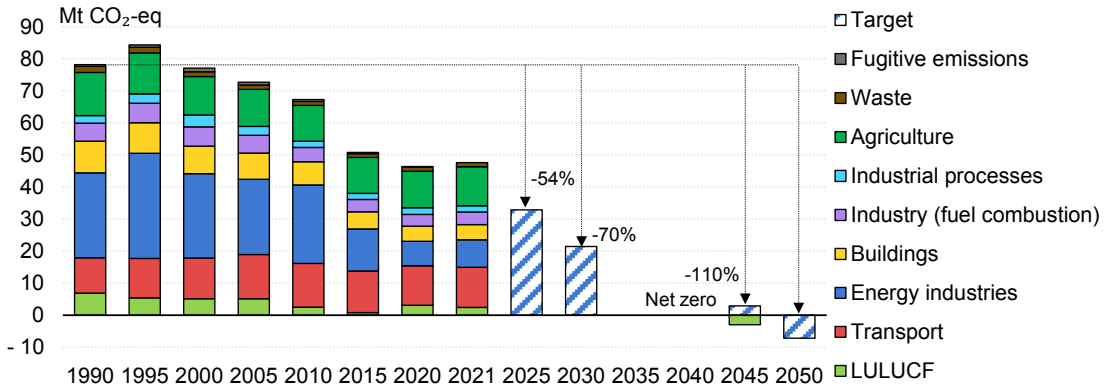
The targets build on the country's long-term strategy, which was presented in 2020 – *Denmark's Mid-century Long-term Low Greenhouse Gas Emission Development Strategy* – and submitted under the Paris Agreement and Climate Programme 2020 (Government of Denmark (2020), Denmark's Mid-century, Long-term Low Greenhouse Gas Emission Development Strategy submitted under the Paris Agreement (and Climate Programme 2020)). In the same year, a broad majority in parliament agreed on the

phase-out of fossil fuel extraction in the North Sea by 2050, leading to the cancellation of the eighth licensing round to extract oil and gas.

GHG emissions in the base year (1990) were 71.4 million tonnes CO_2 equivalent (Mt CO_2-eq), excluding land-use, land-used change and forestry (LULUCF) and 78.8 Mt CO_2-eq including LULUCF. GHG emissions (with LULUCF) peaked at 92.3 Mt CO_2-eq in 1996 and have been declining since, to reach 48 Mt CO_2-eq in 2021, with energy-related emissions of 30 Mt CO_2-eq.

As illustrated in Figure 2.5, in 2021, energy (including transport, energy industries, buildings, industry fuel combustion) accounted for the largest share of emissions (66%), followed by agriculture (27%), LULUCF (5.4%), industrial processes (4.2%) and waste (2.8%).

Figure 2.5 Total greenhouse gas emissions by sector in Denmark, 1990-2021 and targets



Source: IEA analysis based on data from UNFCCC (2023).

Box 2.1 Denmark's climate policy

The Danish Climate Act sets a legally binding climate policy framework for Denmark with a commitment to achieve climate neutrality by 2050 at the latest. Under the Act, Denmark has a legally binding commitment to reduce its GHG emissions by 50-54% in 2025 and by 70% by 2030 from 1990 levels. The Act sets a rolling five-year target, ten years in advance, similar to a carbon budget approach.

The Act also acknowledges four principles for Danish climate policy.

1) Climate challenges are a global problem. Therefore, Denmark must be a leading country in the international climate effort, which can inspire and influence the rest of the world. Denmark also has both a historical and moral responsibility to take the lead.

2) Achieving Denmark's climate goals must be as cost-effective as possible, taking into account both the long-term green transition, sustainable business development and Danish competitiveness, healthy public finances and employment, and that Danish business must be developed and not wound down.

3) Denmark must show that a green transition can be made and at the same time maintain a strong welfare society, where cohesion and social balance are ensured.

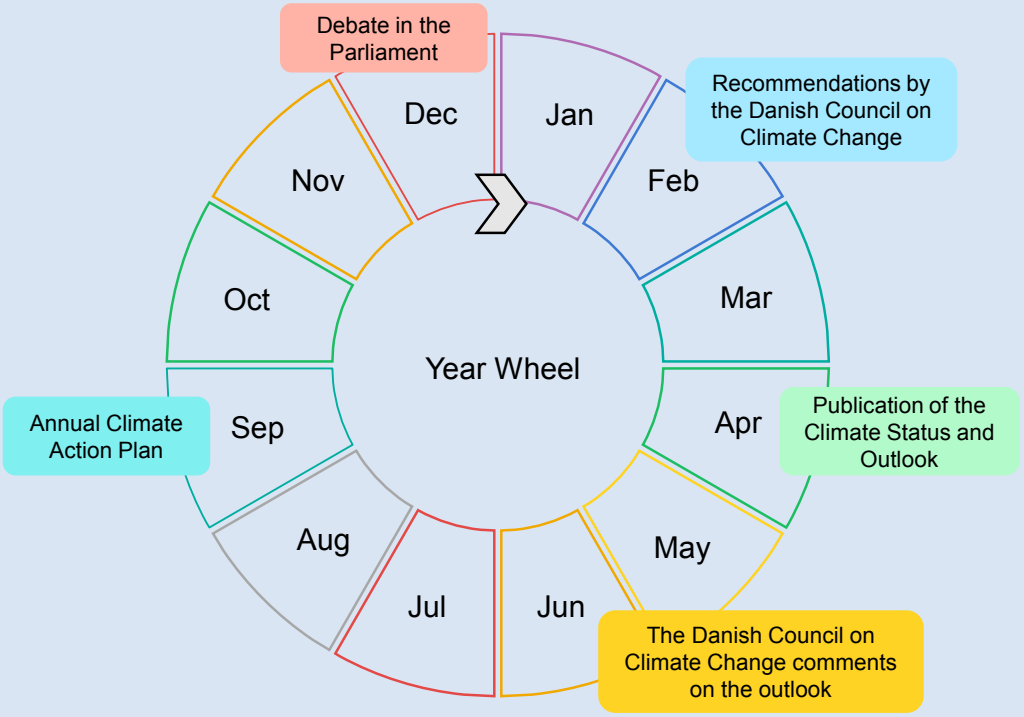
4) The measures that must be used to reduce GHG emissions must lead to real domestic reductions, but at the same time it must be ensured that Danish measures do not simply move GHG emissions outside Denmark's borders.

At the heart of Danish policy making is the annual climate policy review cycle (the year wheel), which has several milestones:

- February: Review of policies and advice by the Danish Council on Climate Change
- April: Projections by the Danish Energy Agency (Climate Status and Outlook)
- September: Annual Climate Action Plan
- October: The DCCC comments on the Annual Climate Action Plan
- Finance Act
- December: Statement of climate effects in the parliament and debate.

The Climate Act requires the government to separately report on Denmark's impact on international emissions, including those pertaining to international shipping and aviation. Furthermore, reductions from electricity produced from renewable sources and the effect of Denmark's bilateral energy co-operation with 15 countries can be taken into account. It also looks at the impacts of consumption (handprint).The Act also asks to evaluate whether Denmark is on track to reach the 2030 target and whether or not the parliament should invoke the "duty to act".

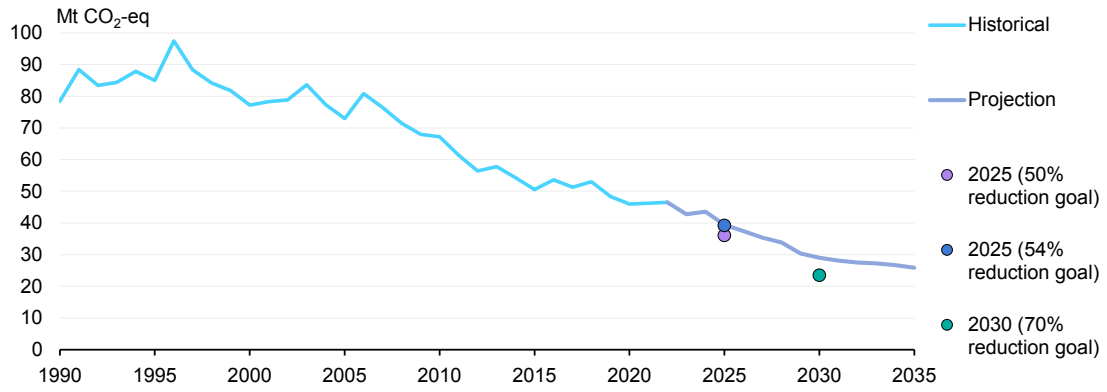
Figure 2.6 Illustration of the year wheel of Denmark



Progress towards targets and gap

Under the year wheel, the DEA evaluates progress to the targets in the annual Climate Status and Outlook. In 2023, the CSO finds that progress to the 50-54% target by 2025 is tight with current stated policies, taking into account reduction efforts of political agreements signed since CSO 2022 and business and investment decisions taken (notably with regard to the CCS tender and the adoption of the biomethane regulation). There's a 0.5-3.7 Mt CO_2, gap to the 2025 targets and an even larger gap towards the 2030 target of 5.4 Mt CO_2-eq.

Figure 2.7 Historic net greenhouse gas emissions and projections for 2035 in Denmark



Notes: Net emissions are calculated after correction for methane regulation and bioenergy.
Source: IEA analysis based on DEA (2023), Climate Status and Outlook 2023.

In 2023, the preparation of the CSO was transferred from the DEA to the Ministry of Climate Change, Energy and Utilities and will become a central tool to track progress and report to parliament on Denmark's future energy consumption and production outlook.

The Danish Council on Climate Change reviewed the strength of climate action towards the targets in its latest Status report 2023 and found that despite the range of ambitions and targets adopted, only a few policies were legally adopted, implemented and financed. The government's main actions were set out under political declarations of intent, strategies and non-binding agreements. The DCCC also noted that one of the key challenges for Denmark's net zero pathway is the limited availability of sustainable bioenergy.

Denmark's climate policies

Stated policies have been presented through agreements on phasing out oil and gas production by 2050, the phasing out of coal use, greater energy efficiency in buildings, the replacement of gas- and oil-fired boilers, a fourfold increase in the production from renewable energy on land by 2030, and a potentially a sevenfold increase of offshore wind by 2030.

The agriculture sector has an emissions reduction target of 55-65% by 2030. To cut emissions in the sector, the Danish government is discussing the implementation of a GHG tax as well as targeted measures based on new technologies.

In March 2023, the government proposed legislation to reduce methane emissions from oil and gas production. Methane emissions largely stem from agriculture activities; 13% are, however, from the energy sector, mainly from vented offshore oil, but also gas production and bioenergy and waste.

In the transport sector, Denmark promotes the use of biofuels, changing the taxation of passenger cars and vans, and increasing incentives for the purchase and use of zero or low-emission vehicles (with an ambition of 1 million zero or low-emission vehicles by 2030) and a distance-based (km) and CO_2-differentiated toll for heavy-duty vehicles from 2025 in line with their CO_2-eq emissions, which came into force in 2022. The ambition is to operate one domestic flight route fossil-free in 2025 and all domestic flights in 2030.

Industrial emissions are concentrated in a few polluters, notably cement. To reduce industrial emissions, a new CO_2 tax will be introduced in 2025 with a phase-in until 2030.

In June 2022, the government reached the Agreement on Green Power and Heat. In the context of ending fossil fuel imports from Russia as soon as possible and accelerating the energy transition, Denmark decided to build more energy islands and accelerate renewable energy production and phase out natural gas use by switching to district heat and green heat pumps. The Agreement on green tax reform of the industry sector was adopted at the same time.

Negative emissions

Denmark's ecosystem and infrastructure are suitable for CCUS, as set out in the White Paper on CCUS.

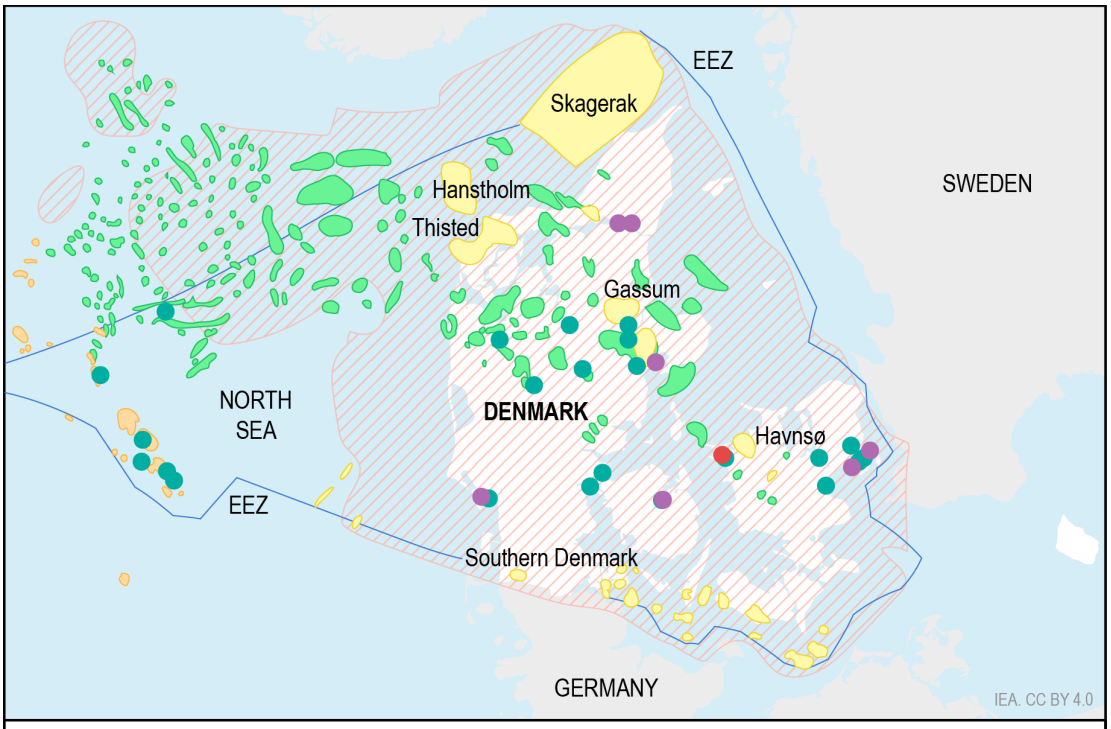
The Danish Subsoil Act has created a robust legal, policy, funding and regulatory framework for CCUS. This framework includes investment in research, development and demonstration (RD&D) and funding/financing mechanisms aimed at demonstrating a full CCUS value chain by 2025. Denmark is promoting such investment through tenders.

According to the Geological Survey of Denmark and Greenland, Denmark's CO_2 storage potential amounts up to 22 Gt CO_2, which is equivalent to more than 500 years of current Danish emissions.

As part of the Climate Agreement for Energy and Industry, in 2021, Denmark announced a CCS strategy that earmarked EUR 2.2 billion (DKK 16 billion) in subsidies for CCS projects, to be distributed in two phases. The first phase is focused on the short term to kick-start the market, and in January 2023, the European Commission approved EUR 1.1 billion for the subsidy scheme. Under the scheme, aid will be awarded through a competitive tender that will be open to companies active in any industrial sector, including waste and energy. Under a 20-year contract, the beneficiary will capture and store an annual minimum of 0.4 Mt CO_2 as of 2026. The aid will cover the difference between the estimated total costs of capturing and storing 1 t CO_2 over the lifetime of the contract and the return expected by the beneficiary. The second phase is yet to be determined. The second scheme will focus on CO_2 utilisation.

In early 2023, Denmark issued its first CO_2 storage licences. In May 2023, the CCUS tender was finalised and the winner (Ørsted) committed to a CCS capacity of 0.43 Mt CO_2 starting from 2026.

Figure 2.8 Carbon capture and storage potential in Denmark



Largest sources of CO_2 emissions	Geological structure	CO_2 storage capacity in million tonnes	
> 1 000 000 tonnes	Sandstone 800 - 3000m	Hanstholm	2753
500 000 - 1 000 000 tonnes	Unexplored areas	Thisted	11039
100 000 - 500 000 tonnes	Investigated areas	Southern Denmark	3000
	Offshore oil and gas fields	Havnsø	926
		Gassum	630
		Skagerak	1000
		Oil and gas fields	2000

Note: EEZ = exclusive economic zone.

The government completed the legal basis to accept and store CO_2 from other countries. In January 2022, Denmark amended the Marine Environment Act to allow for CO_2 storage under the seabed (i.e. offshore CO_2 storage). Previously, the Act prohibited the geological storage of CO_2 offshore. In September 2022, Denmark and Belgium/Flanders signed an agreement on the cross-border transportation and storage of CO_2 – marking the first of such agreements called for under the London Protocol. A new agreement was signed with Germany in April 2023. The necessity to reach bilateral CO_2 transport agreements under the London Protocol is considered a high administrative burden and key hindrance for the fast ramp-up of CCS. There were many calls for an EU agreement in this regard.

The Danish Finance Act 2022 set aside EUR 400 million for projects to achieve negative emissions. A total of DKK 38 billion (or EUR 5.09 billion, 2023 prices) has been allocated to CCUS until 2050.

Carbon storage, be it via CCS or biochar, raises issues of accounting and verification of the feedstock, biogenic carbon content as well as the permanence of CO_2 storage and

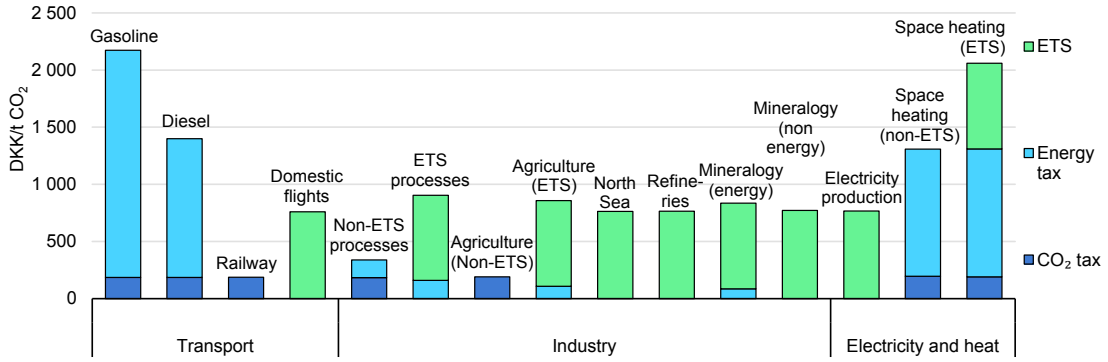
reversal risks. In November 2022, the European Commission adopted a proposal for a voluntary framework to certify high-quality carbon removals, which outlines rules for the independent verification of carbon removals, as well as rules to recognise certification schemes that can be used to demonstrate compliance with the EU framework.

Energy taxation

In 2021, around 45% of Denmark's emissions were covered by an effective carbon rate (by either carbon or fuel tax), according to the 2021 OECD effective carbon rates analysis. And 39% were priced at above EUR 60/t CO_2.

Denmark has imposed a carbon tax since 1992. Today, Denmark imposes multiple taxes on energy and fuels for both environmental and fiscal purposes, taxing energy, CO_2, NOx and SOx (Table 2.1 and Figure 2.9). In 2022, a carbon tax of EUR 24/tCO_2 is levied, mainly on transport and non-district heating. Electricity is taxed through an electricity tax, which has three different levels for different uses. The normal electricity tax for households, public institutions and small businesses is high; a lower level of electricity is applied to heating; the lowest level is applied to industry.

Figure 2.9 Denmark's energy taxation, 2022



Note: DKK = Danish krone.

Source: Expert Group on Green Tax Reform.

Denmark is implementing a green tax reform, which is expected to deliver the single largest contribution to Denmark's 2030 climate goals. The Danish parliament agreed a reform towards higher and more uniform taxes on CO_2 emissions, which is expected to be important for delivering the 70% reduction target and providing incentives to invest in CCS. The green tax reform is expected to provide for a total of 4.3 Mt CO_2-eq reductions by 2030.

The new CO_2 tax will be introduced in 2025 with a phase-in until 2030. Existing taxes will be converted into the new CO_2 tax and adapted to different uses (heating, electricity, road transport, etc.) with incremental step increases each year. The CO_2 tax will also have a broader scope, covering domestic aviation, shipping, rail, fishing and oil refineries as well as ETS industries, building on the 2022 agreement. The CO_2 tax will thus no longer be equal across different uses (Figure 2.9). In the non-EU ETS sector, the carbon tax will increase from EUR 24 per tCO_2 to EUR 100 in 2030, one of the highest levels in the world. Companies under the EU ETS are expected to pay a total EUR 150 per tCO_2 (carbon tax of EUR 50 + projected ETS allowance price of EUR 100). The sector of non-metallic

mineral products (cement and brickworks), which accounts for more than 25% of total emissions from industry, will see a EUR 13 per tCO_2.

With an estimated tax revenue of DKK 1 bn, the green tax reform also provides for new support programmes to facilitate the energy transition and tax credits, such as accelerated depreciation for green investments.

Following advice from the Expert Group on Taxation, the government proposed a GHG tax on the non-energy related emissions from the agricultural sector in 2023.

Table 2.1 Effective taxes on energy in Denmark, 2022

	Unit	Energy tax	CO_2 tax	Nox tax	SO_2 tax	Total[1]
Road transport						
Fossil gasoline	DKK/GJ	135	13.1	0.2	0	148.3
Biogasoline[2]	DKK/GJ	135	0	0.2	0	135.2
Fossil diesel	DKK/GJ	78.6	13.2	0.3	0	92.1
Biodiesel[2]	DKK/GJ	78.6	0	0.3	0	78.9
Electricity[3]	Øre/kWh	0.4	4	0	0	0.4
Space heating						
Heating oil	DKK/GJ	63	13.2	0.3	0	76.5
Natural gas	DKK/GJ	63	10.2	0.2	0	73.4
Coal	DKK/GJ	63	17	0.5	2.6	83.1
Straw, wood, etc.	DKK/GJ	0	0	0.5	1.9	2.4
Electricity for heating[5]	Øre/kWh	0.8	0	0	0	0.8
Electricity, not for heating	Øre/kWh	72.36	0	0	0	72.3
Industrial processes						
Fuel oil	DKK/GJ	4.57	13.28	0.3	0	18
Natural gas	DKK/GJ	4.57	10.28	0.2	0	14.9
Coal	DKK/GJ	4.57	17.08	0.5	2.69	24.6
Straw, wood, etc.	DKK/GJ	0	0	0.5	1.9	2.4
Electricity	Øre/kWh	0.4	0	0	0	0.4
Fuel for power generation						
Within the ETS sector	DKK/GJ	0	0	0-0.5	0-2.6	0-3.1
Outside the ETS sector	DKK/GJ	0	0-17.0	0-0.5	0-2.6	0-22.2

[1]. The public service obligation tariff has been discontinued since the first quarter of 2022 and has thus not been included.

[2]. For mixing with fossil fuels.

[3]. Electricity is indirectly charged with NOx and SO_2 taxes.

[4]. No CO_2 tax on consumption of electricity but the electricity is generated within the ETS sector. The price of the quotas is thereby reflected in the price of electricity.

[5]. For consumption beyond 4 000 kWh in homes registered as electrically heated and electricity used in businesses for space and water heating and cooling.

[6]. The electricity tax was 90.3 Øre/kWh from 1 January to 1 July, then 76.3 ears/kWh until 1 October and then 72.3 Øre/kWh for the rest of the year.

[7]. Varies with type of process between 0 and 4.5 DKK/GJ.

[8]. Does not apply to fuels used for industrial processes or power production within the ETS sector. For this use the rate is 0.

[9]: Varies.

Notes: ETS = Emissions Trading System; DKK/GJ = Danish krone per kilowatt hour; Øre/kWh = 0.01 DKK/kWh

Source: Denmark, Ministry of Taxation.

International climate diplomacy of Denmark

Launched at COP27 by Denmark, the International Renewable Energy Agency and the Global Wind Energy Council, the Global Offshore Wind Alliance aims at installing an offshore wind capacity of at least 380 GW by 2030, with a subsequent increase of 70 GW per year. Thirteen countries have joined the alliance (Australia, Belgium, Colombia,

Denmark, Germany, Japan, Ireland, the Netherlands, Norway, Portugal, Spain, the United Kingdom and the United States).

Denmark also launched the Beyond Oil and Gas Alliance (BOGA) at COP26 with Denmark and Costa Rica as co-chairs. BOGA builds upon the North Sea Agreement, which promotes the phasing out of oil and gas production. BOGA has ten core members (Costa Rica, Denmark, France, Greenland, Ireland, Quebec [Canada], Sweden, Wales, Washington State [United States] and Portugal) two associate members (California [United States] and New Zealand) and five "Friends of BOGA" (Chile, Fiji, Finland, Italy and Luxembourg).

Denmark has 24 energy partnerships, which are supported by the DEA and focus on technical assistance to policy reform and implementation. Denmark promotes government-to-government co-operation and long-term partnerships with 24 countries that contribute to reducing GHG emissions globally; opening and maturing markets for green technology; and strengthening co-operation with countries of strategic significance.

Denmark emits 0.1% of global carbon emissions and therefore supports emissions reductions towards global net zero emissions. According to the OECD, most of Denmark's official development assistance (ODA) is provided as bilateral co-operation, primarily to Africa. Total ODA (USD 2.9 billion, preliminary data) increased slightly in 2021, representing 0.70% of gross national income. Thirty per cent of ODA is targeted towards green investments, of which 60% are earmarked for climate adaptation.

Adaptation and resilience to climate change

In 2023, the IEA released the Climate Resilience Policy Indicator for Denmark. Rising 1.5°C since the 1870s, Denmark's average annual temperature has increased slightly faster than the global average and is projected to continue climbing through the end of the century. The rise in average temperature could reduce overall energy consumption.

Denmark's annual precipitation has increased by roughly 20% since the 1870s, making wet regions wetter, and climate projections indicate a further increase over the century, particularly in winter. More intense precipitation events could raise the risk of floods and aggravate the impacts on the energy system. Rising sea levels due to global warming may also increase concerns of high storm surges. Around Denmark, the water level has risen approximately 2 mm per year since 1900, and by the end of the century it is expected to be 0.3-0.5 m higher than between 1981 and 2010. This rise in sea level could lead to an increase in storm surge height. More intense precipitation events could increase the risk of flooding. Floods resulting from heavy precipitation can disrupt the energy supply by directly damaging infrastructure or forcing electricity suppliers to discontinue power transmission in flooded areas for safety reasons. In July 2011, for instance, a cloudburst (precipitation of extreme intensity over a short period of time) flooded the Copenhagen area, leaving 10 000 homes without electricity for up to 12 hours.

The Danish Meteorological Institute regularly updates the Danish Climate Atlas with projections and regional assessments of the Intergovernmental Panel on Climate Change (IPCC) scenarios. The Climate Atlas analyses the future climate risks and impacts of

extreme weather in order to plan adaptation actions. Denmark uses early warning systems of extreme weather events. The Danish Emergency Agency is the main service responding in the event of a natural disaster.

Although the Danish Strategy for Adaptation to a Changing Climate (2008) identified energy as a key sector and suggested actions for energy system climate resilience, the 2012 Action Plan for a Climate-Proof Denmark did not address the energy sector specifically because Denmark's national climate change impact assessment estimated climate impacts on energy supply to be minimal. A new national climate adaptation plan is currently being elaborated. Among other topics, this plan is expected to discuss municipal planning, high groundwater tables, cross-municipal climate adaptation and protecting Copenhagen against storm water damage. This plan's initiatives are to be implemented over the period 2023-26.

Local adaptation action plans have been developed based on the Danish Nature Agency's guidance document covering flood risk mapping and priority setting for local climate adaptation measures. Most Danish municipalities (96 of 98) are voluntarily revising their climate adaptation plans.

Assessment

Under the 2020 Climate Act, Denmark has a legally binding commitment to reduce its GHG emissions by 50-54% by 2025 and by 70% by 2030 from 1990 levels, and to reach climate neutrality by 2050. In 2022, the Danish government proposed to advance the goal of climate neutrality to 2045 and is committed to achieving a 110% emissions reduction in 2050. The more stringent climate neutrality target for 2045 will require updating Denmark's long-term strategy and the Climate Act. By 2025, a new legally binding climate target also needs to be set for the horizon to 2035 under the Climate Act. The government stated its plans to potentially adjust the 2030 target if needed. Denmark will define a new ambitious 2040 emissions reduction target jointly with other EU countries.

Denmark has been making strong progress in reducing GHG emissions, including land use land-use change and forestry. Total GHG emissions stood at 48.0 Mt CO_2-eq in 2021, including LULUCF, with energy-related emissions of 27 Mt CO_2-eq in 2022. The 2030 target translates into an effort of halving emissions from 2019 levels, which requires a reduction in the next decade similar to that achieved over the past 30 years.

In 2021, energy (including transport, energy industries, buildings, industry fuel combustion) accounted for the largest share of emissions (66%), followed by agriculture (27%), LULUCF (5.4%), industrial processes (4.2%) and waste (2.8%). In 2022, Denmark's energy-related GHG emissions were 27 Mt CO_2-eq, 41% lower than in 2010. After peaking in 2006, energy-related emissions have steadily decreased. Emissions from electricity and heat generation fell by 68% between 2005 and 2021, thanks to the decreasing role of coal and gas and the uptake of renewables. Emissions from other sectors also decreased over the 2005-20 period: -43% for buildings, -26% for industry and -15% for transport.

As regards the LULUCF sector, Danish forests are expected to completely lose their role as carbon sinks due to the high share of more mature forests. In the current projections for 2030, this will nearly outweigh the emissions reductions from agricultural land use.

The Danish Climate Act (June 2020) sets a legally binding climate policy framework with an annual climate policy review cycle (the year wheel). A unique tool for policy review, the year wheel needs to be fully utilised to provide for better implementation. The DCCC's independent review of policy progress towards the fulfilment of the 2030 reduction target towards net zero by 2045 can be strengthened. The sequencing of the year wheel could be adjusted so that the DCCC can base its review of policies and advice on the Climate Status and Outlook published the same year. There is scope for better reflecting all guiding principles of the Climate Act, not only cost-effectiveness, but the clean energy investment, energy efficiency and the social aspects of the transition.

Progress to the 2025 target is good with stated policies but may leave a remaining gap. There is a 0.5-3.7 Mt CO_2-eq gap to the 2025 target but a larger one of 5.4 Mt CO_2-eq to the 2030 target. Agriculture, transport and, to a lesser extent, industry, will be key sectors to close the gap to the 2030 target. The gap to the overall 2030 reduction target is about the size of the gap to the agricultural sector's target (5-7 Mt CO_2-eq). Future progress will be determined by Denmark's capacity to generate negative emissions and emissions reductions in agriculture and transport.

Negative emissions will be necessary if Denmark wants to achieve its net zero target by 2045 and 110% reduction by 2050. The government has identified several key technologies, such as CCS, biochar, direct air capture and carbon sequestration, and bioenergy with CCS. The government needs to evaluate the risks, sustainability impacts, availability of biomass, long-term carbon storage potential and technology costs.

The government identified CCUS as key technology while it is less optimistic about the contribution from direct air capture. The emissions reduction contribution from CCUS is expected to be around 3 Mt CO_2-eq in 2030. Denmark's CCUS approach is enshrined in several strategies and agreements with industry. With the Danish Subsoil Act, the country has created a robust legal, policy, funding and regulatory framework for CCUS. This framework includes investment in research, development and demonstration, as well as funding/financing mechanisms aimed at demonstrating a full CCUS value chain by 2025. Denmark is promoting such investment through tenders.

The green tax reform towards higher and more uniform taxes on CO_2 emissions has been set in motion, building upon the work of the Expert Group on Taxation, starting with the industry sector and focusing on agriculture next. A new CO_2 tax on emissions from the industry sector will be introduced in 2025 with a phase-in until 2030, by which time existing taxes will have been converted into the new CO_2 tax and adapted to different uses (heating, electricity, road transport, etc.) with incremental step increases each year. The CO_2 tax will also have a broader scope, covering domestic aviation, shipping, rail, fishing and oil refineries as well as industries covered by the EU ETS industries, building on the 2022 agreement. The new system will streamline Denmark's multiple taxes on energy and fuels, placing the focus on CO_2 content instead of the energy content of fuels. When implementing the tax reform, the government needs to minimise sectoral exemptions from the CO_2 tax and work through the European Union to address risks of leakage and framework rules for negative emissions and emissions from traded sectors, including industry and agriculture.

In 2022, CO_2 emissions per unit of GDP in Denmark were 0.080 kg CO_2/USD, the fourth lowest among IEA member countries. Every year, a "Global Report" by the DEA assesses Denmark's impact on international emissions (shipping and aviation). To develop a goal

for CO_2 emissions reduction in Danish consumption, the government could develop a strategy for reducing Denmark's global carbon footprint based on a methodology to calculate its global and domestic emissions, including those stemming from imports and exports as well as international aviation and maritime transport.

Denmark's latest adaptation strategy dates back to 2008 followed up with an action plan in 2012, which do not address the energy sector. Denmark's climate policy strategies do not include any adaptation targets. A climate risk assessment with an evaluation of future costs of more extreme weather should be carried out as input to the new National Climate Adaptation Plan.

Recommendations

The government of Denmark should:

- Strengthen the role of the Danish Council on Climate Change as an independent adviser under the year wheel by ensuring appropriate sequencing and scope of its advice, reflecting all the guiding principles of the Climate Act.
- Develop concrete measures to close the 2025 and 2030 gaps, focusing on existing and proven technologies and sectors with significant abatement potential by:
  - bringing forward plans to introduce a greenhouse gas tax in the agricultural sector, building on the Expert Group on Taxation's report.
  - applying appropriate tax incentives, blending mandates and incentives for the roll-out of charging infrastructure in the transport sector.
- By 2025 revise the Climate Act and assess the need to update emissions reduction targets, in line with new climate neutrality goals at the national and European Union levels.
- Prepare a long-term plan and an actionable policy toolbox for negative emissions technologies, including monitoring, reporting and verification, based on a broad assessment of technology cost and readiness and related risks and sustainability impacts, including for biochar, carbon capture and storage, bioenergy with carbon capture and storage, and direct air capture and carbon sequestration.
- Lead negotiations towards EU-wide rules for cross-border CO_2 transport, the inclusion of negative emissions and other sectors in the ETS and certification of low-emission gases.
- Present an updated adaptation strategy and related action plan, assessing impacts on the energy sector and adaptation needs to ensure climate-resilient infrastructure as soon as possible.

3. Energy efficiency

Key data (2021)

TFEC: 559 PJ, -4.4% since 2011

TFEC by source: oil (36%), electricity (21%), heat (20%), natural gas (12%), bioenergy and waste (10%), coal (1%), solar (0.1%)

TFEC by sector: buildings (47%), transport (30%), industry (25%)

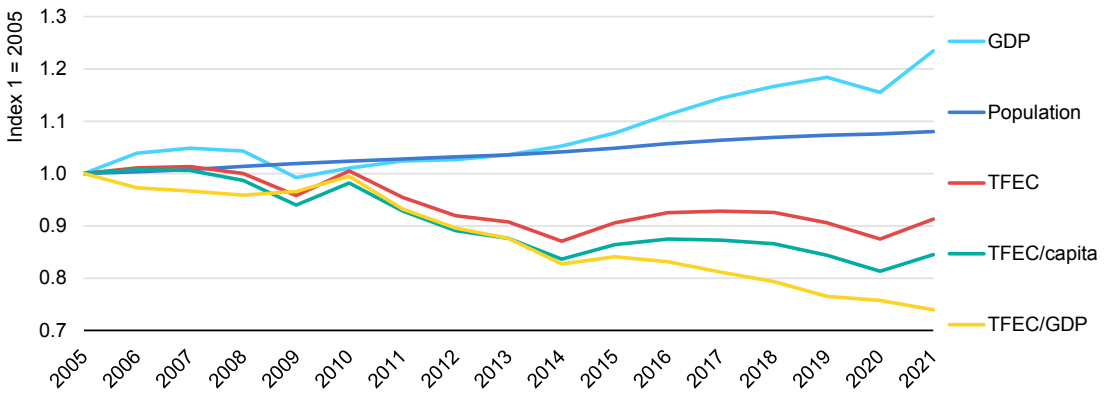
TFEC per capita: 96 GJ/capita (IEA average 106 GJ/capita), -9% since 2011

TFEC per GDP:1.8 MJ/USD million (IEA average 2.4 MJ/USD million), -9% since 2011

Overview

Energy intensity has decreased both in terms of TFEC per GDP (-24% from 2010 to 2021) and TFEC per capita (-13%). Between 2011 and 2021, Denmark's GDP increased by 19%, with a drop of 2% in 2020 due to the Covid-19 pandemic, followed by a rebound in 2021 above the 2019 level (Figure 3.1). Population also increased by 5% from 2011 to 2021. However, TFEC decreased by 10% from 2010 to 2021, showing a significant decoupling between economic growth and energy consumption.

Figure 3.1 Energy demand and drivers in Denmark, 2005-2021

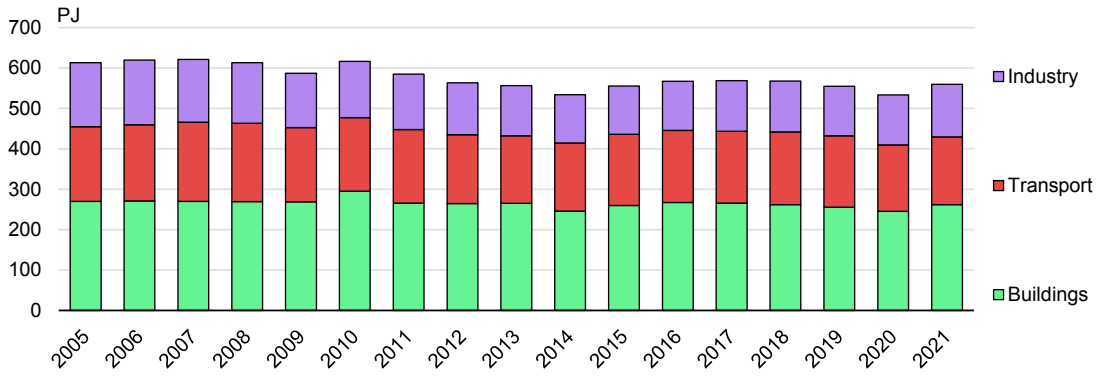


Source: IEA (2023), World Energy Balances.

Energy demand by sector and energy savings

Between 2005 and 2021, Denmark's energy demand (TFEC) decreased by 9.2%, from 613 PJ to 559 PJ (Figure 3.2). The buildings sector was the largest energy-consuming sector in 2021, covering 47% of TFEC, followed by transport (30%) and industry (23%). All sectors have decreased their TFEC since 2005, with industry experiencing the largest decrease of 18%, followed by transport (9.3%) and buildings (3%).

Figure 3.2 Total final energy consumption by sector in Denmark, 2005-2021

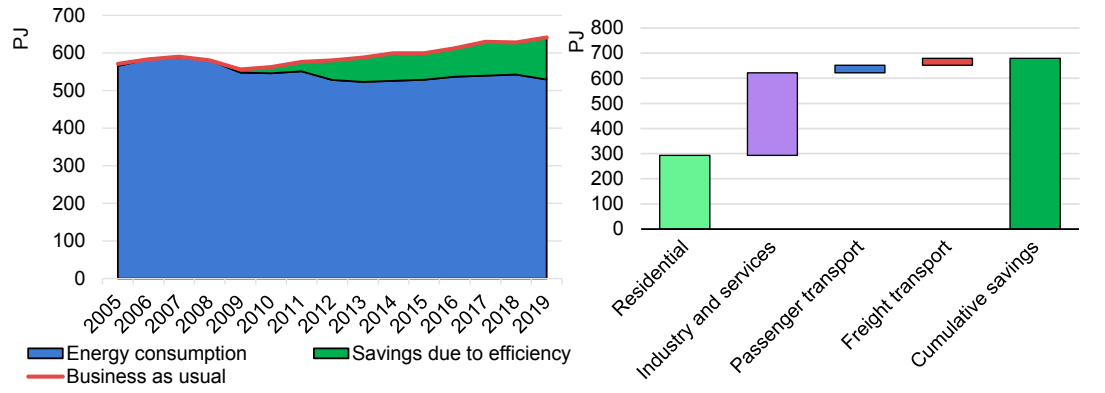


Source: IEA (2023), World Energy Balances.

According to IEA analysis, thanks to energy efficiency gains, between 2005 and 2019, energy consumption in Denmark increased at a slower pace than if energy efficiency-related improvements had not been made. Efficiency gains began to increase rapidly in 2009 (9 PJ), reaching 112 PJ in 2019 (Figure 3.3).

Over the 15-year period from 2005 to 2019, a total of 680 PJ had been saved; 48% came from industry and services, 43% from the residential sector, and 4% each from passenger and freight transport.

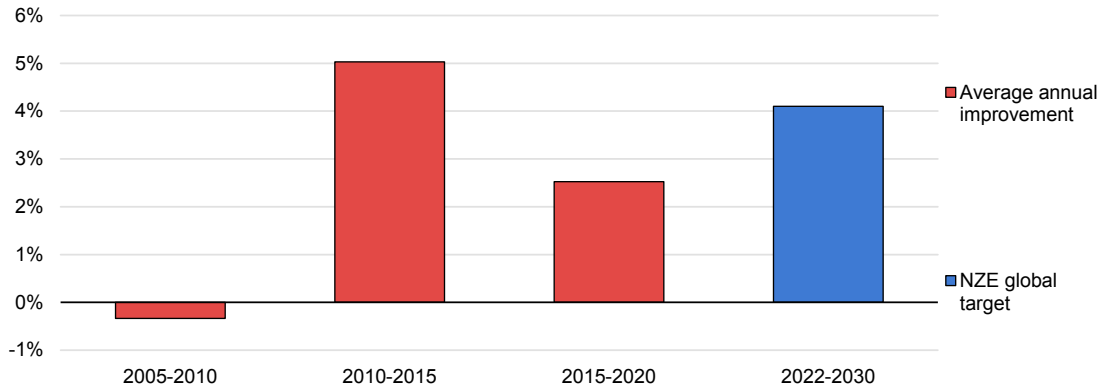
Figure 3.3 Energy savings by sector due to efficiency in Denmark, 2005-2019



Source: IEA (2023), Energy End-uses and Efficiency Indicators.

Between 2005 and 2010, Denmark's average annual energy intensity improvement rate[1] was -0.3%. It increased to 5.0% between 2010 and 2015. However, energy intensity improvements in Denmark slowed down to 2.5% between 2015 and 2020, compared to the net zero aligned global annual improvement target from 2020 to 2030 of around 4.1% per year (IEA, 2023).

Figure 3.4 Denmark's average annual energy intensity improvements and targets



Note: NZE = Net zero emissions.

Sources: IEA (2023), World Energy Balances; IEA (2023), World Energy Outlook 2023 Extended Dataset.

Energy prices and efficiency schemes

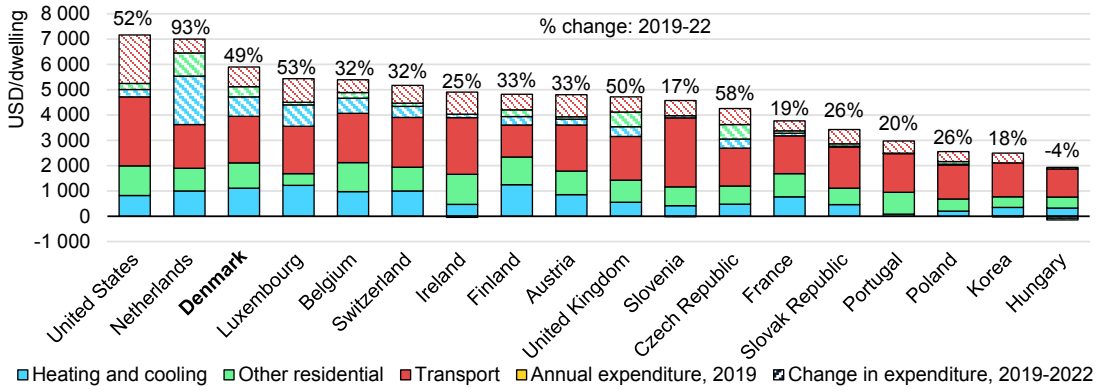
Energy bills play an important role in the amount of household energy consumption and expenditure. Households' exposure to higher energy prices varies greatly across countries.

In 2022, Denmark had one of the highest average household annual energy expenditures after the United States and the Netherlands (Figure 3.5). Between 2019 and 2022, Denmark's household energy expenditure increased by 49% due to higher energy prices.

The energy crisis pushed energy prices up in 2022. Denmark has not implemented price caps, but voluntary price freezes. Based on these price signals, monthly electricity consumption was reduced by 0.8-10.9% and monthly gas consumption by 6.3-27.5%. This can be partly attributed to a strategy based on a combination of general crisis awareness and consumer reaction to price signals. Electricity and gas demand during peak hours were considerably reduced over the year 2022 by 10-15%. In district heating, natural gas consumption has also declined (-15% of heat consumption in 2022). Denmark has achieved long-lasting effects and sustained the price elasticity in the first half of 2023 (Figure 3.6 and 3.7).

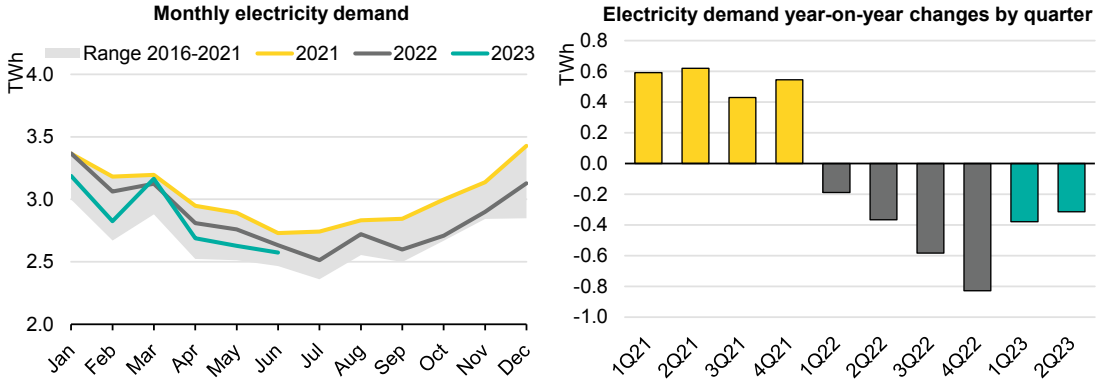
[1] measured as compounded annual growth rate of TES/GDP.

Figure 3.5 Average household annual energy expenditure, percentage change 2019-2022



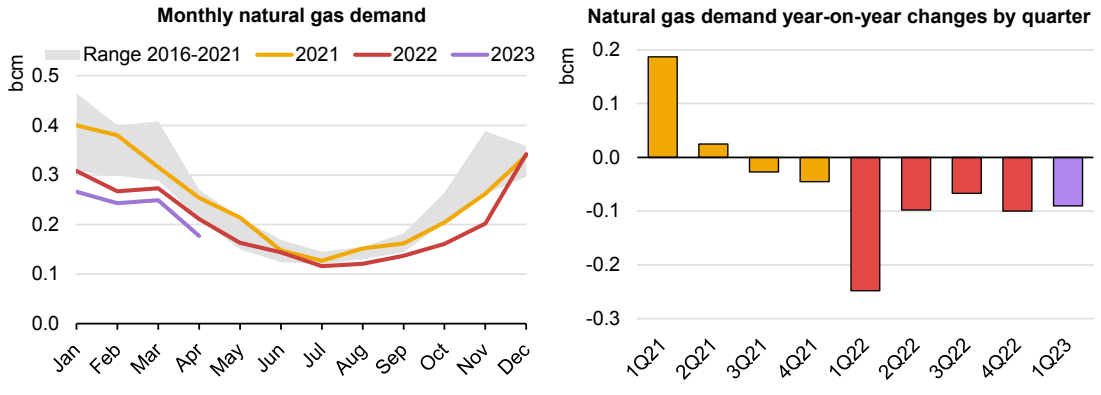
Source: IEA (2022), Energy Efficiency 2022.

Figure 3.6 Monthly electricity demand in Denmark, 2021, 2022, 2023 and 2016-2021



Source: IEA (2023), Real-time Electricity Demand, Generation and Wholesale Prices.

Figure 3.7 Monthly gas demand in Denmark, 2021, 2022, 2023 and 2016-2021



Source: IEA (2023), Monthly Gas Data Service.

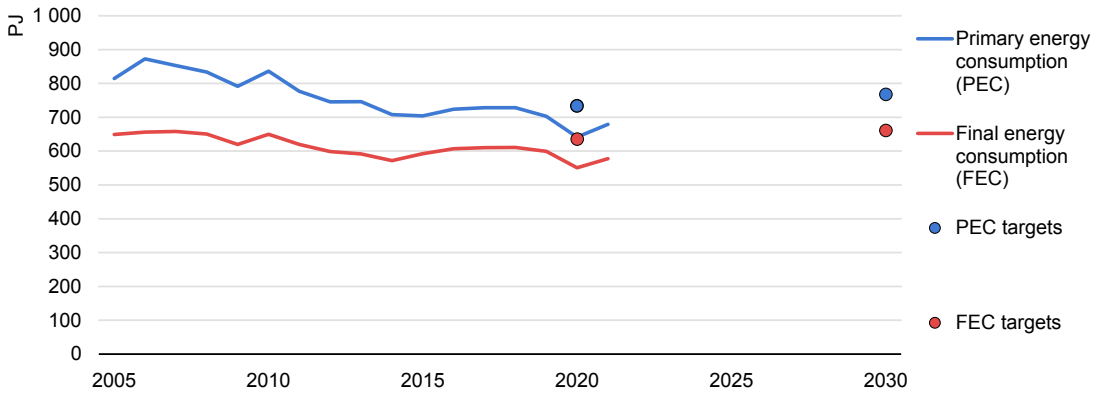
Energy efficiency strategy and targets

The EU Energy Efficiency Directive (EED) sets EU-wide targets to reduce energy demand by 20% by 2020 and by 32.5% by 2030 (compared to the PRIMES 2007 reference scenario for 2030). Each EU member state has national energy efficiency targets for 2020 and 2030 defined as reductions in primary energy consumption (PEC) and final energy consumption (FEC).

Denmark's national targets were set in its National Energy and Climate Plan (NECP). The NECP was adopted in 2019 and reflects the policies and measures in place at that time. Denmark achieved its 2020 targets for PEC and FEC well ahead of schedule (Figure 3.8). The European Commission's assessment of Denmark's NECP conducted in October 2020 noted that the 2030 PEC and FEC targets are of low ambition, considering the need to increase efforts at the EU level to achieve 2030 targets. Since then, Denmark has expanded existing subsidy schemes and implemented new measures for the period 2021-30.

In 2020, the 2030 EU-wide GHG emissions reduction target was increased from 40% to 55%. To support the increased target, the European Union is adopting a wide range of policy updates through the Fit-for-55 package. This includes a significant update to the EED, with an agreement to increase the 2030 target for EU-wide energy demand reduction from FEC of at least 11.7% in 2030, compared with the energy consumption forecasts for 2030 made in 2020. The consumption limit for final consumption will be binding for member states collectively, whereas the PEC target will be indicative. In addition, member states will have to make annual savings of 1.49% of FEC on average between 2024 and 2030, gradually reaching 1.9% by 31 December 2030.

Figure 3.8 Denmark's 2020 and 2030 energy efficiency targets and status, 2005-2021



	2020		2021	2030
	Status	Targets	Status	Targets
Primary energy consumption	641.4 PJ	733.5 PJ	679.4 PJ	767.4 PJ
Final energy consumption	550.5 PJ	635.1 PJ	577.7 PJ	660.9 PJ

Note: The targets do not yet reflect Denmark's indicative objectives under the Energy Efficiency Directive III.
Source: IEA analysis based on EC (2023) NECP; Eurostat data browser.

Energy efficiency policy and measures

Energy savings under EED Article 7

Under Article 7 of the amending Directive on Energy Efficiency (2018/2002), Denmark set a trajectory of 268.5 PJ in cumulative energy savings. Denmark has four measures to achieve this target: 1) a competitive subsidy scheme for private enterprises (DKK 300 million/year in 2021-24); 2) a competitive subsidy scheme for buildings (DKK 200 million/year in 2021-24); 3) efficiency improvements of existing buildings by other measures; and 4) a subsidy scheme to replace oil burners with heat pumps in buildings outside the district heating and gas grids (DKK 20 million/year in 2021-24). In 2021, European Commission regarded these measures as insufficient to achieve the target, as the estimated impacts are less than 30% of the cumulative target.

Denmark was one of the first countries to have introduced a cross-sectoral energy efficiency obligation scheme, which obliged electricity retailers and suppliers to carry out efficiency improvements. According to expert assessments, the scheme did not deliver the efficiency gains needed in the residential sector, but worked well for industry, where it encouraged the creation of an energy service company market (with around 300 consultants conducting audits and advice to industry clients).

The scheme was closed in 2020 and competitive subsidies were introduced with the prime focus of phasing out fossil fuels through a conversion to heat pumps rather than supporting energy efficiency. At the same time, the government reduced the tax on electricity to encourage electrification. In industry, the government introduced a competitive subsidy scheme.

Odyssee-Mure ranked Denmark the seventh most efficient country in the European Union in 2021. The European Energy Efficiency Scoreboard assesses and scores the energy efficiency performances and policies of EU countries, as well as other countries such as Norway, Serbia, Switzerland and the United Kingdom, by country and sector (households, transport, industry and services). The scores are calculated on the following energy efficiency components: the energy efficiency level; the energy efficiency progress (i.e. energy efficiency trends); the energy efficiency policies; and a combination of the three. The ranking reflects a relatively strong ranking for industry, but a deterioration in the ranking for households, transport and services sectors.

Table 3.1 Denmark's rank in the EU Energy Efficiency Scoreboard, 2021

	Level	Trend	Policy	Overall
Industry	**2**	**5**	**8**	**3**
Transport	**22**	**8**	**24**	**18**
Households	**9**	**19**	**18**	**16**
Services	**10**	**8**	**26**	**14**
Overall*	**3 (Lithuania)**	**7 (Greece)**	**16 (Estonia)**	**7 (Ireland)**

* The highest score and benchmark are indicated in brackets.

Source: Odyssee-Mure (2021), 2021 EU Energy Efficiency Scoreboard.

Assessment

Measures to improve energy efficiency, such as smart meters, high-quality appliances, well-insulated buildings, and supporting industrial consumers and businesses to optimise their operations, are effective tools to help achieve both climate and energy security targets while at the same time helping consumers to lower their energy bills.

For instance, although the ownership of electrical appliances increased in Denmark during the period 2000-13, unit consumptions decreased during this period. The unit consumptions of freezers, dishwashers, washing machines, refrigerators and dryers have decreased by 47%, 24%, 31%, 28% and 4.8%, respectively, partially due to the use of more efficient appliances.

Between 2019 and 2022, Denmark's household energy expenditure increased by 49% due to higher energy prices. During the energy crisis in 2022, Denmark had one of the highest average household annual energy expenditures after the United States and the Netherlands. Based on these price signals and overall appliance efficiency improvements, Danish households consumed around 20% less of gas, electricity and district heat in 2022. The IEA encourages the government to ensure that these economic and energy system benefits are long-lasting for society by ensuring peak shaving through demand response, greater digitalisation, strategies for smart consumer behaviour and flexibility of the power system.

During the energy crisis, the cost of operating a gas heating system for the average Danish household increased while that of heat pumps increased less. Homes with a higher energy performance (class A or A+) experienced almost negligible cost increases. Another lesson from the crisis was the shift to time-of-use tariffs that reflect grid costs. This incentivises adjustments to when and what energy is used and has helped reduce and advance the evening peak electricity grid demand in Denmark considerably by 7-10%.

The energy intensity of Denmark's economy decreased by 24% from 2010 to 2020, TFEC decreased by 14% and GDP increased by 19%, showing a decoupling between economic growth and energy demand. Denmark has achieved significant energy efficiency gains in all sectors since 2005. The gains were most significant between 2010 and 2015, when the average annual energy intensity improvement rate was more than 5%. Efficiency gains have slowed since 2015, with a 2.8% annual improvement, lower than the 4.2% required for global net zero emissions by 2050. Efficiency remains an important enabler in order for Denmark to meet its 2045 climate neutrality target.

Among EU countries, Denmark ranked seventh overall on the 2021 Odyssee-Mure Scorecard for its energy efficiency performance. A number of programmes – including the Energy Efficiency Obligation scheme, which encouraged the creation of a market for industrial energy efficiency advice – have ended in recent years or will terminate by 2025.

Denmark achieved its 2020 EU Energy Efficiency Directive targets and has 2030 targets in its first National Energy and Climate Plan. The European Union's Fit-for-55 package increases the continent's ambition for 2030. Denmark will set new indicative targets for 2030 at the national level in its next NECP by 2024 and implement supporting measures to meet the new EU-wide targets under the Energy Efficiency Directive III, including for energy savings and the lead of the public sector in building renovation. In addition, with a

targeted climate neutrality ambition for 2045, energy efficiency efforts will need to be higher than the global average annual efficiency improvements.

The DCCC confirms a solid path towards net zero emissions would involve energy intensity improvements. DCCC analysis shows that Denmark will need more green electricity than expected under the planned expansion of wind and solar power. Energy efficiency can reduce energy infrastructure investment (and associated economic and environmental impact) required to support the transition.

Energy efficiency can be a guiding principle for greater sector integration alongside digitalisation as an enabler and support for efficient investment in grids and aligning supply and demand. There is scope to enhance individual and energy system benefits from digitalisation. While it may be tempting to await direction from the European Union, this could risk losing momentum and delaying affordability, abatement, energy security and other benefits. A new energy efficiency strategy for Denmark could be established to guide efforts across sectors.

Recommendations

The government of Denmark should:

- ☐ Establish an energy efficiency vision and strategy to support the green energy transition, including how to maximise demand management opportunities for the Danish energy system and how to boost digitalisation and achieve cost-effective sector integration.
- ☐ In the context of the Energy Efficiency Directive III, review Denmark's energy efficiency ambition to identify opportunities for cross-sector and sectoral efficiency targets.

4. Renewable energy

Key data (2021)

Renewables in TFEC: 221 PJ, 40% of TFEC (bioenergy: 157.8 PJ, wind 56.1 PJ, solar 5.2 PJ)

Renewables in electricity generation (2022): 28.4 TWh or 81% of electricity generation (wind 18.9 TWh, solar 2.2 TWh, bioenergy 7.2 TWh)

Renewables by sector:* gross final energy consumption 34.7%, electricity 62.6%, heating and cooling 41.5%, industry 32%, transport 10.5%

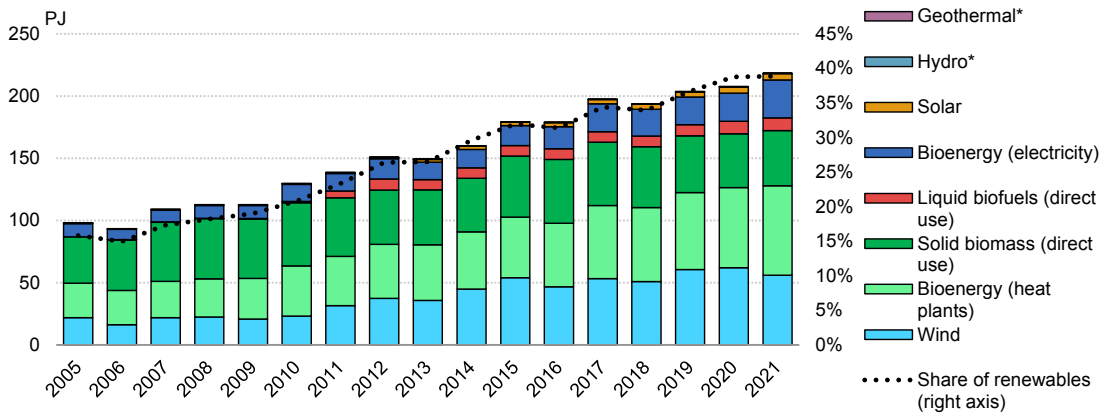
* Eurostat

Overview

Denmark has the fourth-highest share of renewables in TFEC among IEA member countries. In 2021, 40% of TFEC came from renewables, compared to the IEA average of 14%. Renewables in TFEC doubled from 100 PJ in 2005 to 221 PJ in 2021, mostly thanks to their strong increase for electricity generation (see Chapter 9).

The main renewable energy source in Denmark's TFEC is bioenergy (direct use and production of heat and electricity), representing 18% of TFEC, followed by wind (10%), the direct use of solid biomass (8%), liquid biofuels (2%) and solar (1%).

Figure 4.1 Renewables in total final energy consumption in Denmark, 2005-2021



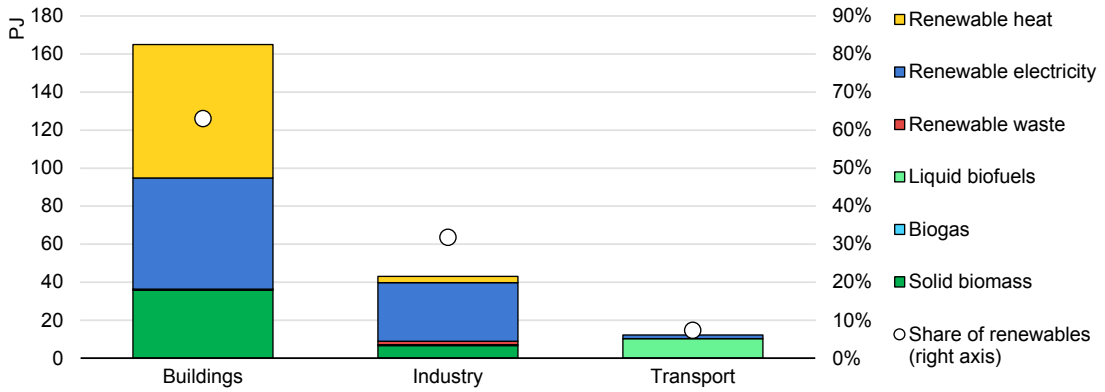
* Hydro and geothermal are negligible.

Source: IEA (2023), World Energy Balances.

In 2021, renewables satisfied 63% of energy demand (TFEC) in buildings, 32% in industry and 7% in transport.

TFEC of the buildings sector was covered for 27% by renewable heat, 22% by renewables electricity and 14% by solid biomass. Industry's TFEC was mainly covered by renewable electricity (24%), followed by solid biomass (5%), renewable heat (3%) and renewable waste (1%). The transport sector's TFEC was covered by liquid biofuels (6%) and renewable electricity (1%).

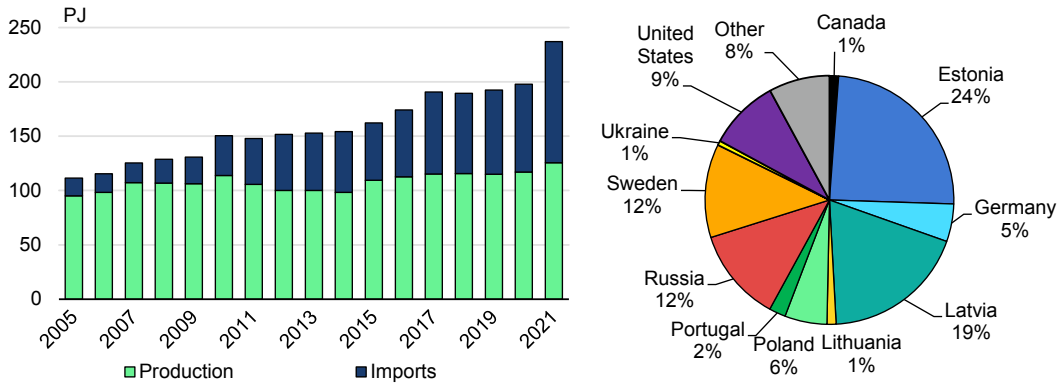
Figure 4.2 Renewable energy by sector in Denmark, 2021



Source: IEA (2022), World Energy Balances.

Denmark domestically produces straw, wood chips, firewood and renewable waste, and imports wood pellets.

Figure 4.3 Denmark's bioenergy and waste imports and production, 2005-2021 (left) and solid biomass imports by country, 2021 (right)



Source: IEA (2022), World Energy Balances.

Domestic production has been slowly increasing and to meet the increasing demand, Denmark has increased its imports. In 2021, solid biomass (wood pellets) accounted for more than half of total imports of bioenergy, which mainly came from the Baltic region (Estonia and Latvia), Russia and Sweden. In 2022, following Russia's invasion of Ukraine, Denmark banned all imports of bioenergy from Russia.

Danish consumption of biomass is higher than what the DCCC considers sustainable for global levels in the long term and it is difficult for Denmark to control the climate footprint of biomass imports. Russia's invasion of Ukraine contributed to a shortage of bioenergy, emphasising the scarcity of bioenergy globally and potential supply risks.

Renewable energy targets

The Danish government's high ambitions regarding renewable energy are based on several broad climate agreements which have the support of all parties in parliament:

- The Climate Agreement of 2020 on Energy and Industry focuses on energy islands, investment in green technologies, and the green transition of industry and transport.
- The Climate Agreement of 2022 on Green Power and Heat announced a fourfold increase of onshore wind and solar PV generation and a fivefold increase of offshore wind for 2030 alongside an ambition of 100% biomethane in gas used for space heating by 2030.
- The Supplementary Framework Agreement of 2023 on the tendering framework for 6 GW of offshore wind and the energy island of Bornholm, which is expected to lay the foundations for a sevenfold increase of installed offshore wind capacity (18 GW) by 2030 and 35 GW by 2050.

At a regional level, Denmark supports regional targets of 19.6 GW by 2030 in the Baltic Sea and 120 GW by 2030 and 300 GW by 2050 in the North Sea. Gathering the leaders from Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, the United Kingdom and the European Commission, the 2023 Ostend North Sea Leaders' Summit announced a major increase in North Sea offshore wind ambitions to boost EU energy security. This builds on the 2022 North Sea Summit in Esbjerg, which brought together energy ministers from Belgium, Denmark, Germany and the Netherlands.

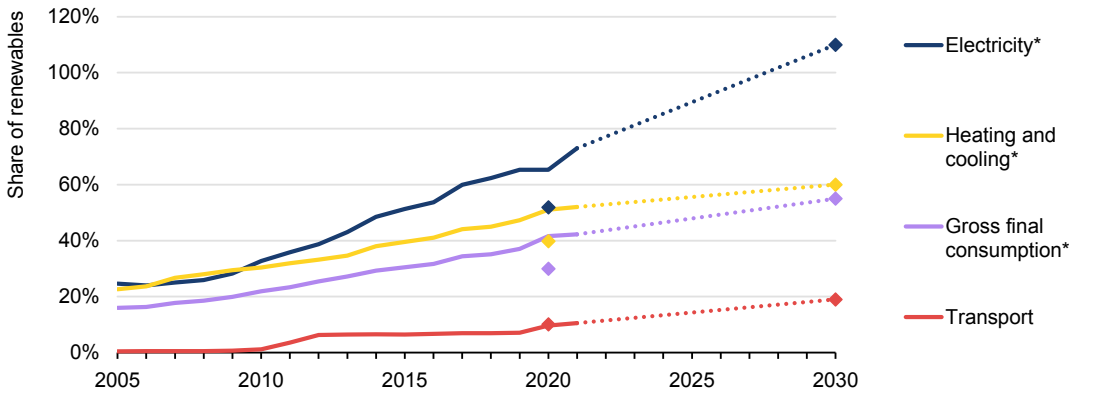
Under the EU Renewable Energy Directive, all EU member states, including Denmark, submitted 2020 and 2030 targets for renewables in gross final energy consumption and must provide indicative trajectories for renewable energy in electricity generation, heating and cooling, and transport. These targets and trajectories aim to support the achievement of EU-wide targets for renewable energy to cover 20% of gross final consumption by 2020 and 32% by 2030.

According to the DEA's latest Climate Status Outlook 2023 (DEA, 2023), Denmark exceeded its 2020 targets in all sectors. In 2021, Denmark had high shares of renewables in gross final energy consumption (34.7%), electricity (62.6%), heating and cooling (41.5%), industry (32%), and transport (10.5%).

Under the CSO 2023's projections, Denmark expects it will overachieve its renewable energy targets, reaching 70% in gross final energy consumption in 2030, 77% in heating and cooling, 41% in transport, and very high shares of renewable electricity at 117%.

In the context of the European Union's Fit-for-55% package, Denmark will respond to the European Union's increased ambition for a binding target for 2030 of at least 42.5% but aiming for 45% under the revision of the Renewable Energy Directive.

Figure 4.4 Denmark's renewable energy targets, trajectories and status, 2005-2030



	Current	Trajectories	
Renewable energy share	**2021**	**2020**	**2030**
Gross final energy consumption	34.7%	30%	55%
Electricity	62.6%	51.9%	>100%
Heating and cooling	41.5%	39.8%	60%
Transport	10.5%	10.1%	19%

* The chart indicates the domestic share of renewable energy in the sectors, including full accounting of bioenergy and excluding statistical transfers, as provided by the Danish government. Eurostat data show lower shares for 2021 due to statistical transfers and the exceptional partial accounting of the contribution of bioenergy in 2021.

Source: IEA analysis based on Eurostat (2023) Share of energy from renewable sources.

Renewable energy support schemes

Until 2022, renewable energy support schemes were largely financed by the public service obligation (PSO) tariff under the Danish Electricity Supply Act. The bulk of the PSO revenues were used to finance renewable subsidies. Today, support is financed directly from the state budget.

The technology-neutral procurement of renewables was discontinued in 2022 and funds have been allocated to a new support scheme to promote renewable energy on less accessible areas such as rooftops and other built surfaces, transport infrastructure, parking areas, and industrial sites, among others. No decision has been taken on how the support is granted.

In 2022, Denmark had an installed offshore wind capacity of 2.3 GW which it expects to increase to at least 9 GW, if not 14 GW, by 2030. Denmark is the global leader in the installation of offshore parks and energy islands.

Offshore wind projects are government-driven through competitive tendering procedures which take the form of a two-way contract-for-difference premium. The latest tender at the Thor offshore wind park reached negative prices and a "lottery" was organised for the winning bidder who for the first time paid the state instead of receiving a subsidy.

A commercial open-door application scheme (similar to oil/gas licensing rounds) was tested but was closed down in 2023.

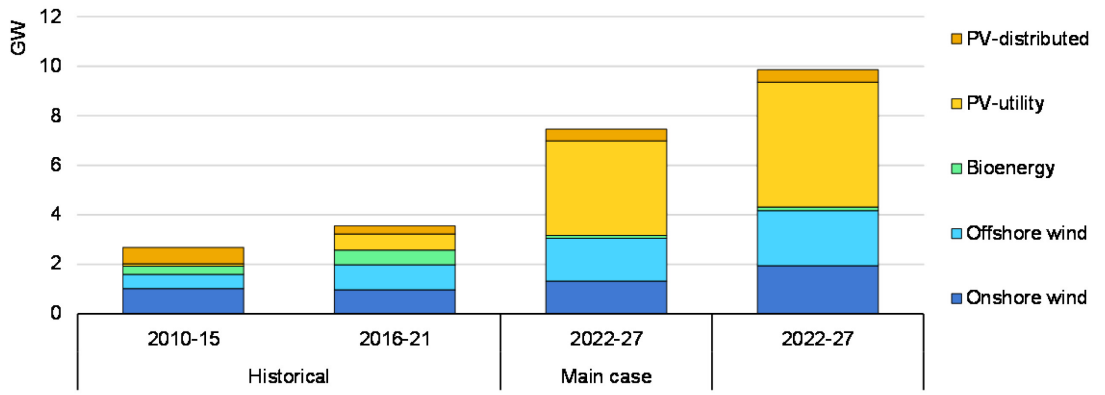
In May 2023, a political agreement was signed on tender frameworks for 6 GW of capacity at the North Sea I (at least 3 GW), Kattegat II (at least 1 GW), Kriegers Flak II (at least 1 GW) and Hesselø (800 megawatts [MW]-1.2 GW) offshore wind areas, with a

further 3 GW at the Bornholm Energy Island. The government announced that it will take a 20% share in the 6 GW offshore wind tenders.

Under the May 2023 political agreements, the offshore wind parks on Nordsøen I, Kriegers Flak II and Kattegat II have received the option of deploying more offshore wind than has been politically agreed upon (so-called “free overplanting”). Taking these upgrades into account, the agreed 9 GW are expected to become 14 GW or more.

The IEA’s Renewables 2022 forecast expected Denmark’s renewable electricity capacity to nearly double between 2022 and 2027 to reach 7 GW (Figure 4.5), led by utility-scale solar PV additions from unsubsidised projects financed through merchant revenues and bilateral contracts. Onshore wind expansion includes the repowering of existing capacity, either through competitive auctions or corporate purchase power agreements. Renewable capacity growth could be 25% higher, or almost 10 GW, with more subsidy-free PV projects based on power purchase agreements or direct participation in the electricity market. Faster commissioning of projects in the pipeline and simplified permitting could provide an additional 1 GW of utility-scale solar PV capacity and 1 GW of wind. In 2023, the state put an additional 9 GW of offshore wind out to tender, with the expectation to be fully operational by 2030 (which is not yet reflected in the above).

Figure 4.5 Renewable capacity additions by technology in Denmark, 2010-2027



Source: IEA (2022), Renewables 2022.

An automated supplement for investment in the distribution grid has been effective since 1 January 2023 to finance additional costs of investments in the distribution grid necessary for the green transition.

With the introduction of tariffs differentiated by geography, developers of onshore wind and solar are facing a cost increase of up to 40%, which changes the commercial viability of existing project pipelines. Also, pay-out schemes for compensating neighbours and municipalities where projects are placed were raised.

Renewable energy permitting

Danish authorities have led global efforts in offshore wind development with a centralised one-stop shop model. The maritime plan constitutes a comprehensive planning for all land interests at sea and seeks to balance considerations of nature, fisheries and renewable

energy. In 2023, a broad political majority has doubled the allocation in the maritime spatial plan of renewable energy and energy islands to approximately 30% of the sea area.

The government takes the lead in identifying suitable offshore wind zones, selecting sites, organising permits as well as awarding the financial envelope through tenders. Permitting procedures and tenders are awarded independently of litigation procedures. Tenders can be rolled out at scale and are industrialised. However, no such models are in place for onshore wind and solar PV, and municipalities lack capacity to process the demands for land access, siting and permitting.

There were also delays in grid connections. Targets set for early 2030 have been delayed further; the energy island on the west coast of Denmark will be ready by 2033 while the Bornholm Energy Island will be established first and ready by the end of 2030.

In 2022, the government had formed a national energy crisis staff (NEKST) involving relevant social actors to ensure the national co-ordination of an accelerated roll-out of renewable energy, notably by:

- replacing natural gas with renewable energy in district heating
- identifying barriers for scaling up solar and wind on land as well as offshore wind and recommending measures to accelerate the expansion
- supporting expansion of the electricity grid where there are currently already challenges with capacity and contribute to ensuring that the expansion is at the forefront of electricity consumption and the production of power from renewable energy.

To fast track the deployment of renewables, NEKST considers a stronger role for the government to support the creation of energy parks to guide private investors. A national screening of areas suited for onshore wind turbines, solar PV and PtX has been carried out. In 2023, the DEA provided guidance to companies wishing to establish PtX facilities in Denmark. The goal is to simplify and accelerate the application and permit process for PtX. The new rules were established by the PtX Secretariat, which was created in 2022.

In June 2023, authorities from three ministries (the Ministry of Climate, Energy and Utilities; the Ministry of Rural Affairs; and the Ministry of Environment) created an inter-ministerial team with the Danish Environmental Protection Agency, and the Planning and Rural Development Agency. The team will be the municipalities' central contact point in the state and support faster processes.

Box 4.1 Best practices for accelerating permits and authorisations

In the European Union, countries are implementing procedures for faster permitting and siting, including in the context of the Council Regulation (EU) 2022/2577 laying down a framework to accelerate the deployment of renewable energy.

Among the lessons learnt is the importance of giving political leadership to local communities, such as the presidential instructions requiring local state representatives to accelerate permitting and ensure their success in line with long-term targets (France) or the creation of a task force of the Ministry of Culture and Sports and the Ministry of the Environment and Energy to unlock the definition of suitable areas (in relation to cultural heritage in Greece). Better spatial planning can be ensured by identifying large enough

zones appropriate for developers, defined by the government and in line with long-term targets, communicated clearly to the industry. In Spain, the government proceeded with the top-down definition of areas of low and moderate sensitivity where renewables have priority in permit-granting. Greece introduced the definition of go-to areas with clear exclusion zones.

Simplifying procedures and offering advantages for small-scale installations is applied in Poland, where no building permit is required for installations below 50 kilowatts (kW). In Sweden, network operators do not charge a fee for installations below 43.5 kW and such installations cannot be refused by the network company.

Many countries promote shorter permitting deadlines. For instance, Belgium (Flanders) has fully transposed the Council Regulation (EU) on shorter deadlines. The overriding public interest is guaranteed in Austria and Germany, where renewables benefit from presumption of overriding public interest.

A recent internal evaluation by Solar Power Europe of the implementation of EU permitting rules and guidance, notably under the revised Renewable Energy Directive and the EU Council Regulation 2022/2577, showed mixed results.

Assessment

Denmark is a global renewable energy leader with very ambitious targets, and global expertise in offshore wind development and permitting, and which enjoys very high shares of wind power and bioenergy.

In 2022, renewables played a key role in buildings and industry, but mostly in electricity, where variable renewables reached a significant share, thanks to contributions from wind (54%) and solar (6.3%). When adding biomass (20.7%), Denmark reached a share of 81% of renewable energy in power generation.

Thanks to a high use of bioenergy and the significant expansion of wind in the last decade, Denmark has the fourth-highest share of renewables in total final energy consumption among IEA member countries. In 2021, 40% of TFEC came from renewables (221 PJ), compared to the IEA average of 14%.

Under the EU framework, Denmark overachieved its 2020 renewable targets in all sectors. Over the past three years it has increased its targets further. Denmark aims to reach 50% renewables in TFEC by 2030. Under the most recent projections, the DEA projects a share of 70% of renewables in gross final energy consumption by 2030 and 77% in heating and cooling. This places Denmark in a position to help other EU countries attain their targets through statistical transfers.

The most recent ambitions for renewable energy were set in the Danish Climate Agreement on Green Electricity and Heat in 2022 in the context of phasing out fossil fuel use in general and imports from Russia in particular. Denmark aims to quadruple onshore wind and solar PV generation by 2030 (no split by technology is indicated), which translates into a total electricity generation of 50 TWh in 2030. The preliminary Danish

offshore wind ambition is to reach 12.9 GW and 35 GW by 2050 at the latest and potentially more, depending on the European demand for green power.

In the period towards 2030, Denmark's renewable energy development is entering the next phase of very high shares of renewables across energy consumption.

Bioenergy and waste are mainly used for heat and electricity generation, slowly replacing fossil fuels. Denmark domestically produces straw, woodchips, firewood and renewable waste. It imports wood pellets. Domestic production has been slowly increasing, but Denmark increasingly relies on imports to meet the increasing demand. In 2021, solid biomass (wood pellets) accounted for more than half of total imports of bioenergy, mainly from the Baltic region (Estonia and Latvia), Russia and Sweden. In 2022, following Russia's invasion of Ukraine, Denmark banned all imports of bioenergy from Russia.

Increasing supply, sustainability and efficiency concerns indicate that there is a need for the government to articulate the future role of solid and liquid biofuels in the Danish energy system with a clear perspective of their contribution to generating emissions reductions in aviation and negative emissions and removals (biogenic CO_2 and bioenergy with CCS) through targets and road maps.

The government aims to increase the GHG reduction requirement for diesel and gasoline while capping the use of first-generation biofuels. Today, the share of renewables in transport stands at 10%, but the DEA's projection is to reach 42% by 2030, quadrupling in only 7 years.

In 2023, the tender of the Thor offshore wind facility reached negative bids and the winner was drawn in a lottery. Project developers are ready to pay the Danish state to develop their projects. Danish technology-neutral procurement of utility-scale solar PV, onshore and offshore wind near costs, hydropower, and tidal wave power were discontinued in 2022. Changes in the support scheme, the introduction of locational grid charges, the slow pace of grid investment and onshore permitting barriers are among the key factors impacting renewable investment.

Overall, offshore wind development on energy islands also experienced delays in implementation and are expected to be commissioned after 2030. No onshore wind turbines were installed in 2022 and few projects are announced for 2023. The build-out of solar power is expected to be halved in 2023 due to changing framework conditions.

The government is, however, working on the framework conditions in 2023 and is taking a very active stance in making progress on the ground. The DEA estimates that after a temporary slowdown, the expansion is expected to pick up again in 2024 and 2025. The IEA's latest forecast expects Danish renewable capacity to reach 7 GW by 2027 and that does not even include the newly announced offshore wind tenders, including the possibility for building more capacity than tendered.

In May 2023, the government announced that it will take 20% shares in the next four offshore wind farms to develop 6 GW. To incentivise the lowest levelised cost of electricity, future tenders should reflect the value, not the volume, of energy and raise the bar to reflect a number of non-price criteria.

A national screening of areas suited for onshore wind turbines, solar PV and PtX is being carried out. The government wants to strongly support and accelerate municipalities'

planning process by establishing energy parks to shorten the permitting process. In 2023, it set up an inter-ministerial team with the key agencies involved in planning projects to help municipalities fast-track renewable energy deployment and the transition on the ground. The government could review Europe's best practices, which support faster permitting, including one-stop shop registrations onshore for renewables, with digitalisation, designated areas and overriding public interest obligations.

Recommendations

The government of Denmark should:

- Embed NEKST in an inclusive approach to co-ordinate across government, notably with municipalities, to identify barriers and recommend actions to accelerate the expansion of renewable energy, notably grid investment and make municipal planning processes for renewables efficient and transparent, including by ensuring time limits for decisions and fast-tracking permits for energy parks.
- Improve the design of state tenders by reflecting non-price criteria with minimum requirements that in addition to flexibility, technical and financial capabilities also raise the bar for environmental, social and governance commitments when developing offshore wind.
- Articulate the role of solid and liquid biofuels in the Danish energy system with a clear perspective of their contribution to generating emissions reductions in aviation and negative emissions and removals (biogenic CO_2 and bioenergy with CCS) through targets and road maps.

5. Buildings

Key data (2021)

Energy consumption: 262 PJ (heat 41%, electricity 28%, bioenergy and waste 14%, natural gas 14%, oil 3%, solar 0.2%), -1.4% since 2011

Share of total final energy consumption: 47%, +2% since 2011

Share of total energy-related GHG emissions: 10%; -39% since 2005

Share of renewable energy: 40%, +15.7% since 2011

Targets and strategies

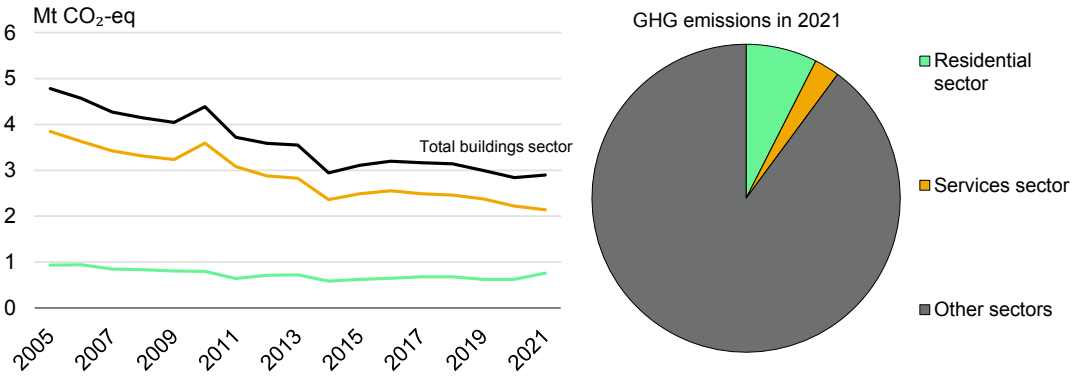
In 2020, the Danish government adopted the Agreement on Green Housing. In the context of the energy crisis, the Agreement on Green Power and Heat (2022) provided for the phase-out of gas use in space heating by 2035 and the political ambition of 100% 'green' gas by 2030 at the latest. The Agreement also included a proposal to prohibit new district heat projects that use fossil fuels. In 2023, the share of gas consumption consisted of 39% biomethane and 61% natural gas.

Energy use and emissions in buildings

Buildings in Denmark are no longer a major source of emissions thanks to an increasing use of district heating, electricity and bioenergy. Since 2005, emissions from energy consumption in buildings have fallen by more than 39%, accounting for 10% of total energy-related GHG emissions in 2021 (Figure 5.1). In fact, thanks to the reduction in carbon intensity, residential buildings' emissions have decreased strongly.

However, the buildings sector remained Denmark's largest energy-consuming sector in 2021, covering 47% of TFEC. Residential buildings, accounting for 69% of buildings' TFEC in 2021, have a larger energy demand than services sector buildings.

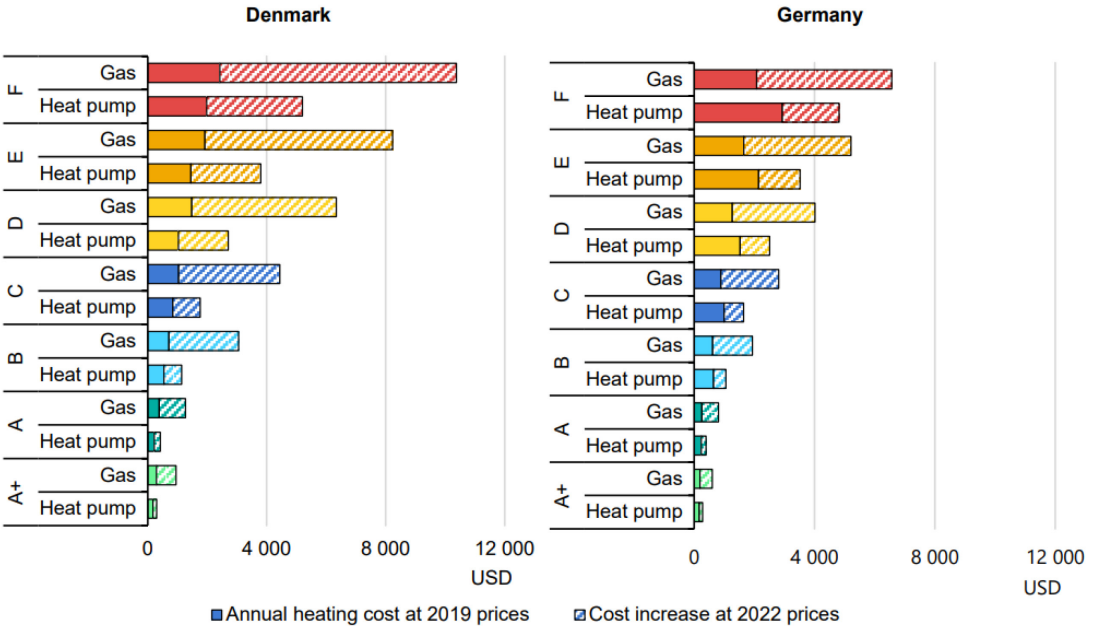
Figure 5.1 GHG emissions in buildings in Denmark, 2005-2021



Source: IEA (2023), World Energy Balances.

As of September 2022, there were 4.4 million buildings in Denmark.[2] Of these, two-thirds are residential buildings, 16% services sector buildings and 17% in the industry sector. Forty-four per cent of buildings were built before 1950, while 12% were built after 2000. Of buildings with energy performance certificates (EPCs), in the residential sector almost half (46%) have an EPC between A and C. The share increases to 49% for municipal buildings and 67% for industries. It is lower for governmental and regional buildings, at 32-35%.

Figure 5.2 Annual heating cost for 100 m² of a gas versus a heat pump, by building performance, in Denmark and Germany, at 2019 and September 2022 prices



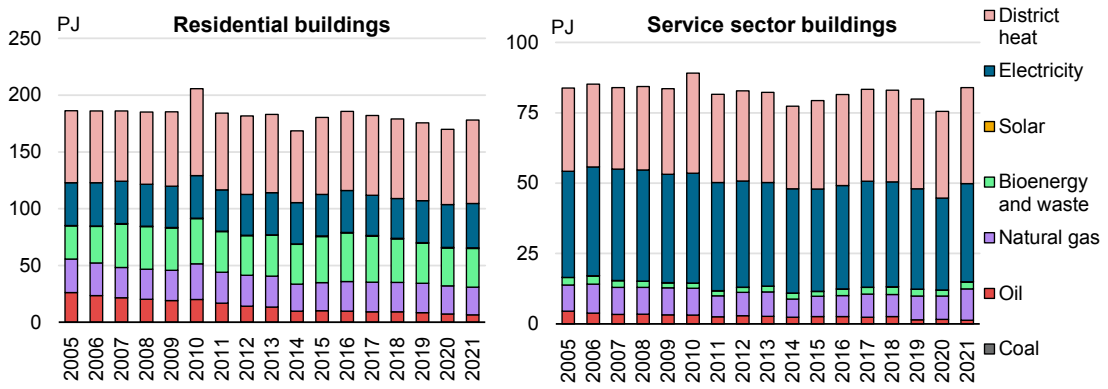
Notes: The figure uses Denmark's threshold values of building performance classes in energy consumption per m² for comparison between the two countries. Class A relates to the Danish A2015, Class A+ to the Danish A2020.

[2] The DEA holds a central register of buildings and dwellings (BRR), with data on buildings in Denmark.

Source: IEA (2022), Energy Efficiency 2022.

Prior to the recent energy price increases, the cost of operating a more efficient heat pump was only marginally less than that of a gas system in a B or C energy performance-related home (Figure 5.2). However, the situation for an average household changed dramatically during the energy crisis in 2022, when the cost of operating a gas heating system increased by around 330%, while that of an electric heat pump rose by around 100%.

Figure 5.3 Total final energy consumption in buildings by source in Denmark, 2005-2021



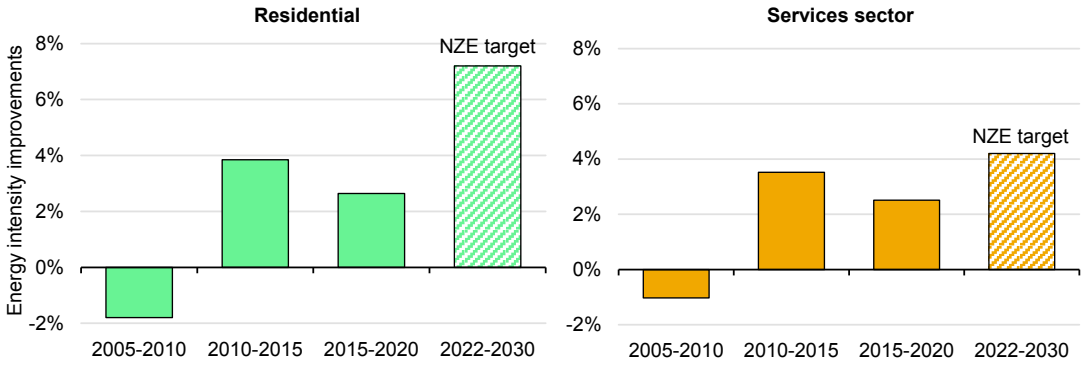
Source: IEA (2023), World Energy Balances.

The largest part of energy consumption in residential buildings is covered by district heat (41%), followed by electricity (22%), bioenergy and waste (19%), natural gas (14%), and oil (4%) (Figure 5.3). In services sector buildings, the largest source of energy is electricity (42%), followed by district heat (41%), natural gas (13%), bioenergy and waste (2.9%), and oil (1.5%).

Average annual energy intensity improvements in buildings[3] have increased since 2010 and are higher than the IEA average (Figure 5.4). The residential sector improvements reached 3.8% in the period from 2010 to 2015 and it was 3.5% in the services sector over the same period. However, the rate of the energy intensity improvements of the residential sector is much lower than the global benchmark of a net zero rate of improvement of 5.6% per year globally.

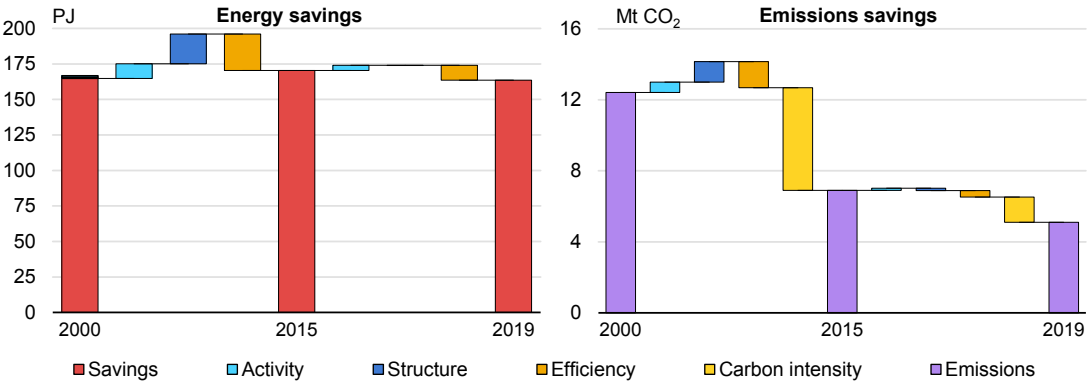
[3] measured as compounded annual growth rate of, respectively, residential and services TFEC/GDP.

Figure 5.4 Average annual energy intensity improvements in the residential and services sector (2005-2020) in Denmark and targets (2022-2030)



Sources: IEA (2023), World Energy Balances; IEA (2023), World Energy Outlook 2023 Extended Dataset.

Figure 5.5 Residential estimated cumulative energy and emissions savings broken down by activity, structural change and energy intensity in Denmark, 2000-2019

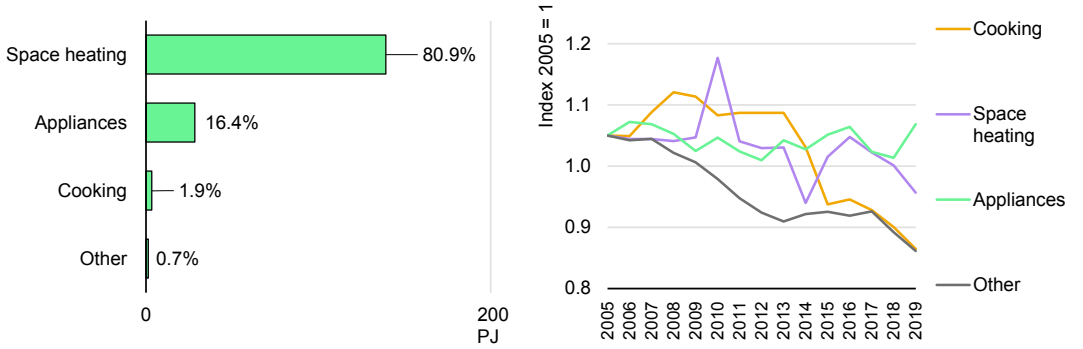


Source: IEA (2023), Energy End-uses and Efficiency Indicators.

The decomposition analysis in Figure 5.5 suggests that, between 2000 and 2019, energy consumption in the residential sector has remained constant in spite of intensity-related improvements. Concurrently, emissions savings due to energy efficiency were constant over the 2000-2019 period.

Space heating drives energy demand in the residential sector and was responsible for 81% of energy demand in the sector in 2019 (Figure 5.6). Appliances accounted for 16.4% of residential energy demand, cooking for 1.9% and other activities for 0.7%. Energy consumption for cooking, space heating and other activities has decreased since 2005, while that of appliances has remained stable.

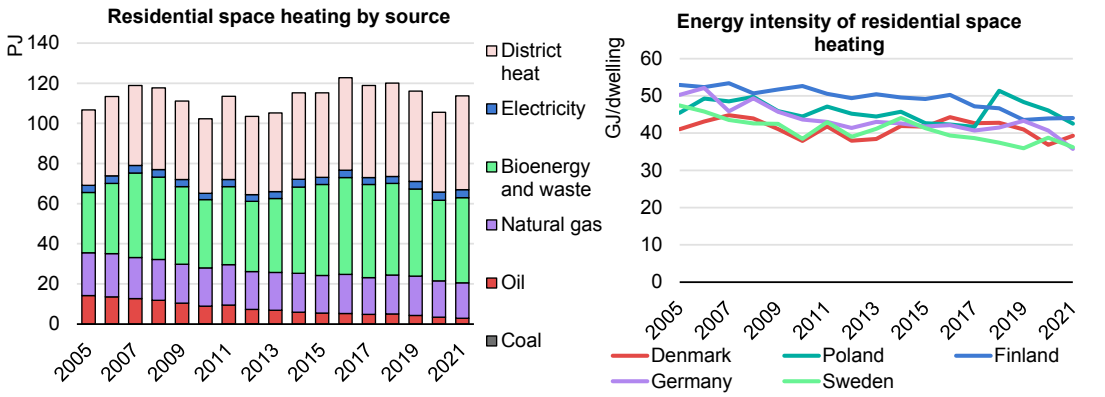
Figure 5.6 Energy consumption in the residential sector by end use, 2019 and change since 2005



Source: IEA (2022), Energy End-uses and Efficiency Indicators.

Denmark's energy intensity of residential space heating decreased by 23% between 2010 and 2019, yet remains the highest among Finland, France, Germany and Sweden (Figure 5.7). The energy intensity of space heating (439 MJ/m^2) in Denmark is much higher than the global benchmark in the net zero scenario (285 MJ/m^2) in 2021.

Figure 5.7 Space heating energy consumption by source, and energy intensity of space heating in selected countries, 2005-2021



Source: IEA (2022), Energy End-uses and Efficiency Indicators.

District heating covers almost half (49%) of the energy needs for space heating in Denmark, followed by bioenergy and waste (25%), natural gas (17%), oil (5%), and electricity (4%). In 2022, 400 000 dwellings used gas and 50 000 dwellings used oil heating. With the goal of phasing out gas for heating by 2035, the government plans to convert those dwellings to district heating, heat pumps and small-scale heating solutions.

Efficiency policies and measures in buildings

Regulation

The Executive Order on Building Codes regulates minimum energy performance standards for new buildings. EPCs are a key tool to encourage renovation and assess the performance of existing and new buildings. Approximately 70 000 EPCs are issued annually in Denmark.

Incentives

The government aims to phase out oil and gas boilers and boost energy renovations. To achieve these goals, it has set four subsidy schemes: 1) the building pool, financing energy renovation and conversion from oil and gas boilers to heat pumps; 2) a scrapping scheme, providing subsidies for companies that supply heat pumps on subscription to households; 3) a disconnection scheme, providing fee exemption on the disconnection for citizens converting from gas boilers to heat pumps or district heating; and 4) the district heating pool, supporting energy-efficient district heating.

Information

Households and industry have advanced smart electricity meters. Smart charging of heat pumps and EVs is fully functional in Denmark. It allows all consumers and grid operators to control their consumption based on hourly electricity pricing, which is spot-price indexed. There are no smart meters in the gas sector. Regulation allows all distributors to introduce a grid tariff to charge peak hour pricing and thus manage consumption indirectly.

Two projects are of interest in the smart grids/digitalisation space: Danish DSO Elværk to build a digital twin of its electricity network in over six years. Danish DSO VISUE partnered with Greenbird and Danish IT company, KMD, to deliver a data integration solution using Greenbird's Utilihive digital integration hub. The digital platform breaks down silos, increases the visibility of data from smart meters and enables end-to-end monitoring.

Renewables energy policies in heating and cooling

Denmark had the highest share of district heat in TFEC among IEA countries in 2020, at 19%. Furthermore, district heat represents Denmark's main source for residential space heating, covering two out of three dwellings in 2021 (see Chapter 3), placing Denmark in the lead position among IEA member countries.

Over the years, the fuel mix of Denmark's heat generation has evolved. High shares of natural gas and coal in 2011, together accounting for 50%, decreased to 16% in 2021, replaced by an increasing share of biomass. In 2021, solid biomass represented 51% of district heat generation, up from 10% in 2011. Heating from waste heat has increased considerably in recent years, accounting for 9% of total heat production in 2021.

In April 2022, the government put forward plans to convert up to 200 000 households from natural gas heating to district heating by 2028. This corresponds half of the Danish households that currently use natural gas to heat their homes. They will be converted to district heating. The government agreement included a proposal to prohibit new district heat projects that use fossil fuels. Municipalities oversee heat planning. There is no longer an obligation to connect to a heat network, but consumers are free to choose other heating technologies, such as heat pumps, depending on gas and electricity prices. With high gas

prices but lower taxation on electricity in 2022, the heat pump market has grown, but is constrained by supply chain bottlenecks across Europe.

The Danish Utility Regulator imposed a price cap on district heating and removed the mandatory connection to district heating, while promoting a more efficient regulation to incentivise investment.

In 2019, the government terminated the support scheme for decentralised co-generation plants fuelled with natural gas. Denmark removed electricity and heat co-generation requirements for district heat to promote the electrification of the heating sector by giving heating companies more freedom with regards to which technology to adopt, such as geothermal. In 2020, fuel support schemes for natural gas were also removed. In 2021, the electric heating tax was lowered to the EU minimum. Another measure to promote renewable sources of district heat is the introduction of a price cap on the total costs of waste heat in 2022 and tax relief to promote the use of waste heat.

Under the CSO 2023's projections, Denmark expects to overachieve its renewable energy targets, reaching 77% in renewable energy sources for heating and cooling.

In co-generation, the driver for reducing fossil fuel dependence has been the switch from coal to bioenergy (woodchips, wood pellets and straw). Households are the second-largest consuming sector of firewood and woodchips for their heating. Heat pumps are being considered in Denmark for heating and cooling production in individual households and private companies. In particular, heat pumps represent a sustainable alternative for houses for which district heat is not a viable option.

Thanks to effective support policies, biomethane production has seen continuing growth. Danish gas consumption in 2023 is expected to consist of 35% biomethane and 65% natural gas. CSO 2023 expects biomethane to make up 100% of gas consumption in line with the political ambition of 100% green gas by 2030. A total of DKK 13.6 billion in state aid (EUR 1.82 billion) will be allocated through 2050 for six tenders to support green gas production.

In March 2023, the Danish parliament passed a law that will exempt geothermal heat projects from the price regulation already in place. District heating companies and geothermal operators will determine the price through a contract, which establishes a ceiling on the costs that consumers will pay for heat of geothermal origin. Geothermal is estimated to have the potential to cover 15-20% of Danish heating demand. The new regulation will allow for the development of the large-scale geothermal plant located in Aarhus.

Assessment

Energy-related GHG emissions from buildings have seen a 39% drop from 2005 to 2021, as average annual intensity improvements in buildings have increased since 2010 albeit at a lower rate from 2015 to 2020 compared to the period 2010-2015, when the average annual rate of energy intensity improvements in Danish residential buildings was 2.6%.

Energy efficiency policies for buildings in Denmark include regulation, incentives, subsidies to industry and households, and information tools. On the regulation side, the Executive Order on Building Codes regulates minimum energy performance standards for

new buildings. Energy performance certificates are a key tool to encourage renovation and assess the performance of existing and new buildings. Approximately 70 000 EPCs are issued annually. Currently one-third of buildings have an EPC. The website SparEnergi.dk communicates how to reduce energy consumption along with the different subsidies available.

Enabling mechanisms in Denmark include the extensive availability of smart electricity meters and smart charging of heat pumps and EVs. This will allow consumers and grid operators to control consumption based on hourly electricity prices.

The production of district heat from renewable sources is at the core of Denmark's green policy. Since the IEA's last review in 2017, the government has introduced several policies to promote district heat while phasing out gas and oil boilers for heating.

Incentives are in place to support Denmark's goal of phasing out oil and gas boilers and boosting energy renovations for existing buildings. The building pool finances energy renovation and conversion from oil and gas boilers to heat pumps; a scrapping scheme provides subsidies for companies that supply heat pumps on subscription to households; a disconnection scheme provides a fee exemption on the disconnection for citizens converting from gas boilers to heat pumps or district heating; and the district heating pool supports energy-efficient district heating. Work is ongoing to improve these pools and schemes.

While the energy efficiency of public buildings is relatively inefficient – only one-third of governmental and regional buildings have an EPC between A and C – budget limits constrain municipalities' ability to progress major improvements in public buildings.

There is scope to better sequence and target support through the building pool. For example, the annual cost of operating a heat pump per 100 m² is almost USD 4 000 for E-rated buildings and less than USD 2 000 for C-rated buildings, according to the IEA's *Energy Efficiency 2022*. Ensuring E-, F- and G-rated buildings are renovated before a heat pump is installed would improve operational efficiency, lowering energy bills and reducing pressure on the grid. The worst performing houses are more present in certain regions, and more often owned by lower socio-economic groups. A higher rate of support for vulnerable consumers would improve energy, social and health outcomes.

Individual bill savings, together with demand flexibility in the energy system, could be improved through smart meters for heating, with a focus on digitalisation in the energy efficiency strategy.

Recommendations

The government of Denmark should:

- ☐ As part of the energy efficiency strategy, review and amend the design of the building pool to ensure appropriate sequencing and targeting of improvements.
- ☐ Remove the budget limit for green projects for municipalities and regions to allow them to prepare for likely stronger requirements for public buildings in line with the Energy Efficiency Directive III.

- Roll out smart meters for heating to increase flexibility in pricing and demand for more households.
- Swiftly finalise heat planning, derisk grid development and communicate to consumers the connection time with a view to maintain the social, environmental and economic benefits of the district heating network.

6. Transport

Key data (2021)

Total final energy consumption of the sector: 167 PJ

Share of total final energy consumption: 30%, -1% since 2011

Share of total energy-related GHG emissions: 40%; -15% since 2005

Share of alternative fuels in transport TFEC: liquid biofuels 6.1%, renewable electricity 1.2%, natural gas 0.3%

Targets and strategies

The Agreement on Green Road Transport (4 December 2020) paved the way for the promotion of "green" vehicles in Denmark. The Agreement is expected to result in the deployment of 775 000 zero and low-emission cars on Danish roads, contributing to a reduction of 1 Mt CO_2 by 2025 and 2.1 Mt CO_2 by 2030. The Agreement ultimately targets 1 million vehicles by 2030, or the equivalent of converting a third of Denmark's vehicle fleet.

In April and June 2021, the Danish government signed several agreements on public co-financing of transport infrastructure, notably publicly accessible EV charging points and renewable refuelling infrastructure for heavy-duty vehicles, among others.

Building on the green tax reform agreement in 2022, from 2025 onwards, energy taxation for non-road transport will reflect CO_2 content and emissions.

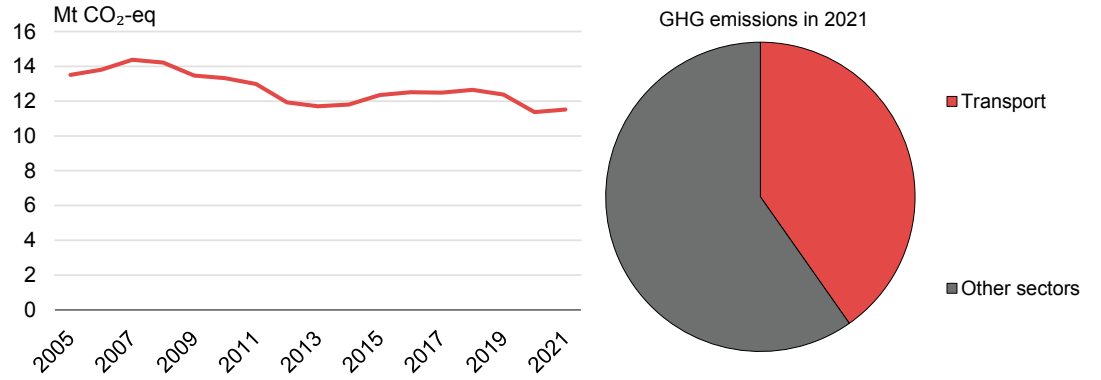
Denmark's new Coalition Agreement of 2022 aims for "greener transport" by:

- examining an increased ambition for the number of clean EVs roll-out in Denmark based on the review of the Road Transport Agreement
- continuing to promote zero emission vehicles based on the pool for fuel infrastructure for heavy road transport from the Infrastructure Compromise, notably the conversion of fleets and the installation of charging stations
- creating one fossil-free domestic route by 2025 and fully decarbonising domestic aviation by 2030, financed by the passenger tax on air travel (averaging DKK 100)
- accelerating the transformation of heavy-duty transport, maritime transport and aviation, including by promoting electrification and green fuels.

Energy use and emissions

The transport sector is the largest emitter of energy-related GHG emissions (Figure 6.1) in Denmark, accounting for 40% of the total and the second-largest consuming sector, accounting for 30% of total TFEC (167 PJ). Emissions have remained stable over recent decades.

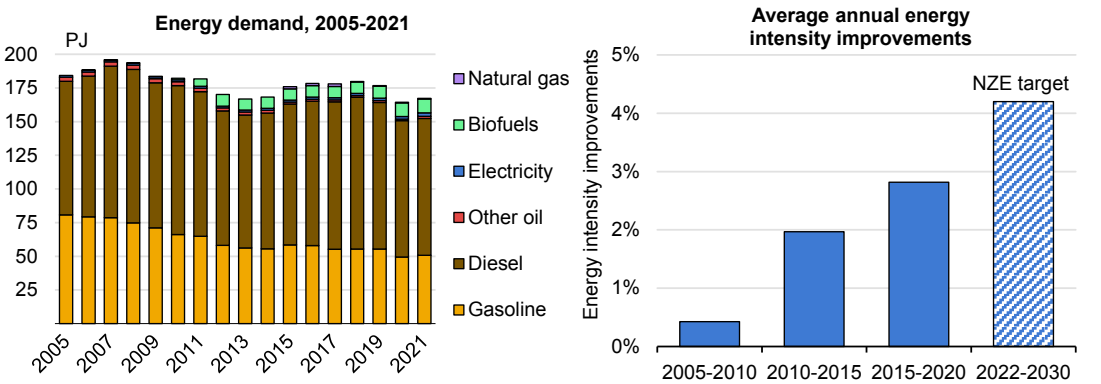
Figure 6.1 Energy-related CO_2 emissions in transport in Denmark, 2005-2021



Source: IEA (2023), Greenhouse Gas Emissions from Energy.

Energy consumption in the sector decreased by 3% from 2010 to 2019 and dropped another 5% from 2019 to 2021 due to the Covid-19 pandemic (Figure 6.2). Diesel and gasoline almost entirely cover transport energy demand, accounting for 62% and 30%, respectively. Biofuels covered 6.1% of transport TFEC in 2021, followed by electricity (1.5%) and natural gas (0.3%). Road transport accounted for 94% of transport energy consumption in 2021.

Figure 6.2 TFEC in transport in Denmark by source (2005-2021) and average annual energy intensity improvements in the transport sector (2005-2020) and targets (2022-2030)

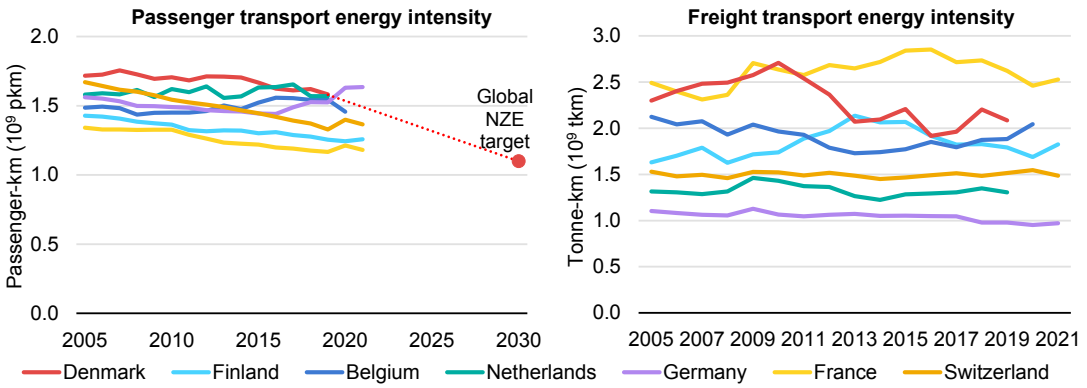


Notes: Transport sector demand excludes international aviation and maritime transport.

Sources: IEA (2023), World Energy Balances; IEA (2023), World Energy Outlook 2023 Extended Dataset.

Average annual energy intensity improvements in transport[4] have been increasing in Denmark and reached an annual improvement rate of 2.8% between 2015 and 2020. However, this needs to further increase to achieve net zero. While the energy intensity of both passenger and freight transport is decreasing in Denmark (Figure 6.3), it is still the highest among other European IEA member countries. Based on the IEA's Tracking Clean Energy Progress, further efficiency efforts are needed to align with the global net zero ambitions in the transport sector.

Figure 6.3 Energy intensity of passenger and freight transport in selected European countries, 2005-2021



Note: NZE = net zero emissions.

Source: IEA (2022), Energy Efficiency 2022.

Transport vehicle fleet

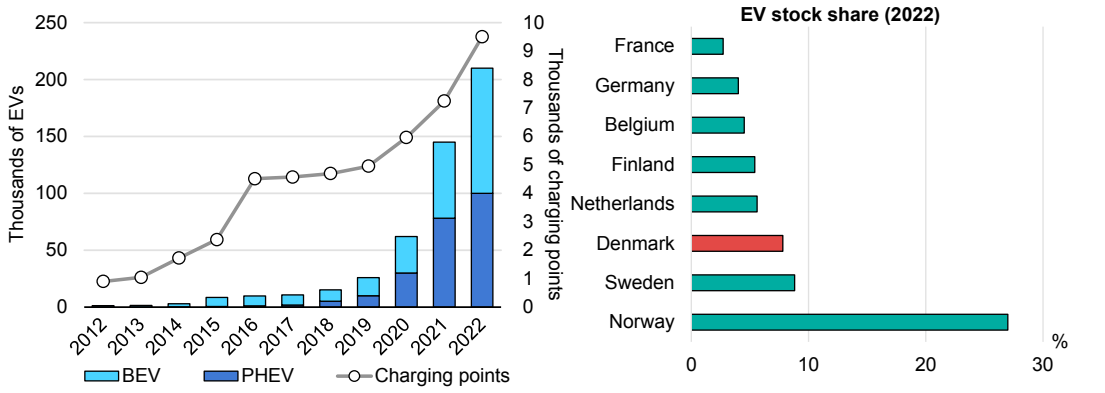
At the end of 2021, the Danish transport vehicle fleet consisted of 2.78 million cars, 373 000 vans, 43 000 trucks and 8 700 buses. Two-thirds of cars were fuelled by gasoline, just 3% by diesel and 6% were EVs. Vans, trucks and buses were mainly fuelled by diesel, with buses also being electric (4%) and fuelled by gas (2%).

EVs experienced a fast increase in Denmark, from 79 vehicles on the road in 2010 to 220 000 in 2022 (Figure 6.4).

In 2022, there were 110 000 battery electric vehicles (BEV) and 110 000 plug-in hybrid electric vehicles (PHEV) along with 9 500 public charging points. Denmark's share of EVs in the car stock was 7.8% in 2022, lower than Norway (27%) and Sweden (8.8%) but higher than Finland (5.4%) and the Netherlands (5.5%). EVs are scaling up in Denmark but deployment has been stagnating recently.

[4] measured as compounded annual growth rate of transport TFEC/GDP.

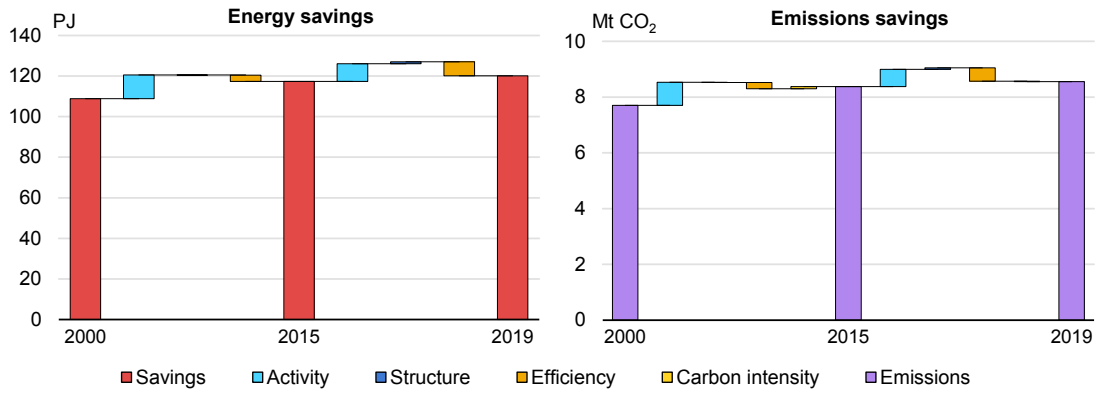
Figure 6.4 Registered electric vehicles and public charging points in Denmark, 2012-2022 and the share of electric vehicle stocks in 2022 for selected countries



Notes: Charging points include both slow and fast chargers.

Source: IEA (2023), Global EV Data Explorer.

Figure 6.5 Passenger transport estimated cumulative energy and emissions savings broken down by activity, structural change and energy intensity in Denmark, 2000-2019



Source: IEA (2023), Energy End-uses and Efficiency Indicators.

Policies and measures in the transport sector

Carbon pricing and energy taxation

In the context of its green tax reform, in June 2022 the Danish government introduced a CO_2 tax for non-road transportation. Since 2015, the CO_2 tax in transport was relatively high compared to industry. With the green tax reform, the CO_2 tax now includes more sectors: rail, aviation and maritime transport. Sectors already subjected to the EU ETS (i.e. aviation and maritime from 2024 onwards) will receive a discount. Heavy-duty trucks will also be subject to a kilometre-based toll based on CO_2 differentiation.

Electrification

The government no longer provides subsidies for the purchase of electric cars, but some subsidies do exist for the purchase of electric and hydrogen trucks and for installing

charging stations. Heavy-duty trucks are also further incentivised by the introduction of a kilometre-based toll based on CO_2 emissions.

The 2020 green transportation deal lowered tax rates for low- and zero emission vehicles until 2035. Registration and ownership taxes are linked to CO_2 emissions. Low-emission vehicles are defined as emitting less than 50 g CO_2/km. In addition, EV charging benefits from low electricity taxes. EVs also benefit from preferential and free parking in the municipality of Copenhagen.

In 2022, the Danish government launched an information campaign to encourage consumers to save fuel and money when driving (Danish Road Directorate's savings council (2022), Save money on the road) The campaign includes ten actions with associated financial savings per year, with a video for each of them to better transmit the message to the public.

In the rail sector, the government targets full electrification of public railways by 2030. The Infrastructure Plan 2035 envisages DKK 86 billion investment through 2035, mainly for railway projects. It also includes funding for long-distance bike lanes and an electric bicycle charging network.

Biofuels policy and targets

Denmark focuses on a mix of electrification and the development of hydrogen, e-fuels and biofuels to achieve GHG reductions. Denmark has a GHG reduction requirement (not a blending mandate). The current target is a 3.4% GHG intensity reduction – biofuels can be used to reach the target. The target increases from 3.4% in 2022 to 7% in 2030. Biofuels are exempt from the CO_2 tax levied on gasoline and diesel. In 2023, the government proposed to close the reduction gap to the 2025 target by increasing the GHG reduction requirement in gasoline and diesel and imposing a ceiling on the use of first-generation biofuels.

Assessment

The Danish government has focused on promoting low and zero emission vehicles, targeting a mix of electrification, biofuels and e-fuels to achieve GHG reductions in transport. Denmark does not have a comprehensive road map for decarbonising the transport sector. However, the Agreement on Green Transport of 2020 promoted the vehicle roll-out through taxation policy. Alongside the green tax reform, these measures slowly advance the decarbonisation of the Danish transport sector. The government plans to review the Agreement on Green Road Transport by 2025.

In 2021, energy demand in the transport sector accounted for 30% of TFEC. Diesel and gasoline almost entirely cover transport energy demand, accounting for 61% and 30%, respectively. Biofuels covered 6.1% of transport's TFEC in 2021, followed by electricity (1.1%) and natural gas (0.3%). Road transport accounted for 94% of transport energy consumption in 2020.

Average energy efficiency in transport has been increasing in Denmark, with an annual improvement rate of 2.8% between 2015 and 2020. However, this needs to further

increase to achieve net zero by 2045. The energy intensity of both passenger and freight transport is decreasing in Denmark, but remains among the highest in European IEA member countries.

It is, however, welcome that Denmark has moved to a GHG reduction requirement and does not have minimum blending mandates. The current target is a 3.4% GHG intensity decline, which will increase to 7% by 2030. Biofuels can be used to satisfy the target and are exempt from the CO_2 tax levied on gasoline and diesel.

For domestic aviation, the government aims at making domestic flights fossil fuel free by 2030. The government announced a decision to impose a passenger tax on domestic and international flights of an average of DKK 100 (EUR 13.39) per flight.

Electric vehicles have expanded rapidly in Denmark, from 79 vehicles on the road in 2010 to 220 000 in 2022. Of these, 110 000 were BEVs and 110 000 PHEVs, along with 9 500 public charging points. Denmark has an ambition to reach 1 million zero- and low-emission vehicles by 2030, corresponding to over one-third of the total fleet. The share of EVs in Denmark's car stock was 7.8% in 2022, lower than in Norway (27%) and Sweden (8.8%) but higher than in Finland (5.4%) and the Netherlands (5.5%).

Policies in the transport sector focus on the adoption of low- and zero emission vehicles, with lower tax rates for registration and charging, subsidies for charging infrastructure (including for trains), the conversion of conventional parking spaces to recharging sites, free parking for EVs in the municipality of Copenhagen, and the electrification of public rail. In 2022, the Danish government also launched an information campaign to encourage consumers to save fuel and money when driving. The campaign includes ten actions with associated annual savings, with a video for each to better communicate the benefits to the public.

While policies in the transport sector will create incentives for more efficient transport and fuel choices, there is room for improvement. The framework for EV charging infrastructure and taxation risks reducing competition, insufficient finance for future road maintenance and construction, and being disadvantageous for residents with shared parking or in dense urban areas.

Denmark is speeding up the electrification of the transport sector. Compared to its regional neighbours' roll-out in the Netherlands and the Nordic countries, Denmark is catching up after a late start and the number of EVs is now on the rise. For EVs and plug-in-hybrid electric vehicles, a staggered tax reduction is foreseen from 2023 to 2035. However, the roll-out of the EV charging infrastructure is lagging, notably as bigger municipalities are very densely populated and already have a lack of on-street parking. The taxation on EVs and the lack of charging stations does not incite the Danish consumer to trade their fuel-combusted car for an EV.

The number of electric vans, smaller trucks/city-logistics and local buses is growing. Regarding heavy-duty transport, long-distance buses and trucks, greater policy clarity is needed to support electrification, including through infrastructure planning.

Recommendations

The government of Denmark should:

- Complete efforts under the green tax reform and introduce a kilometre-based tax for all vehicles, with higher rates for fossil fuel vehicles.
- Resolve charging infrastructure arrangements for public buildings, private residences with shared spaces and dense urban areas.
- Review regulatory (including taxation) arrangements for EV charging providers to ensure consumer choice and a competitive market.
- Evaluate the use of the mass balance method for the blending calculation of biofuels (sustainable aviation fuel) to prevent the need to duplicate storage and distribution infrastructure.

7. Industry

Key data (2021)

Total final energy consumption: 130 PJ

Share of total final energy consumption: 23%; -6% since 2010

Share of industry emissions in total energy-related GHG emissions: 25%; -5% since 2005

Share of industry sector in total final electricity consumption: 37%

Targets and strategies

The Agreement on Climate and Industry and the Agreement on Green Tax Reform of the Industry Sector provided for a new approach to decarbonising industry based on higher carbon taxation and technology and innovation.

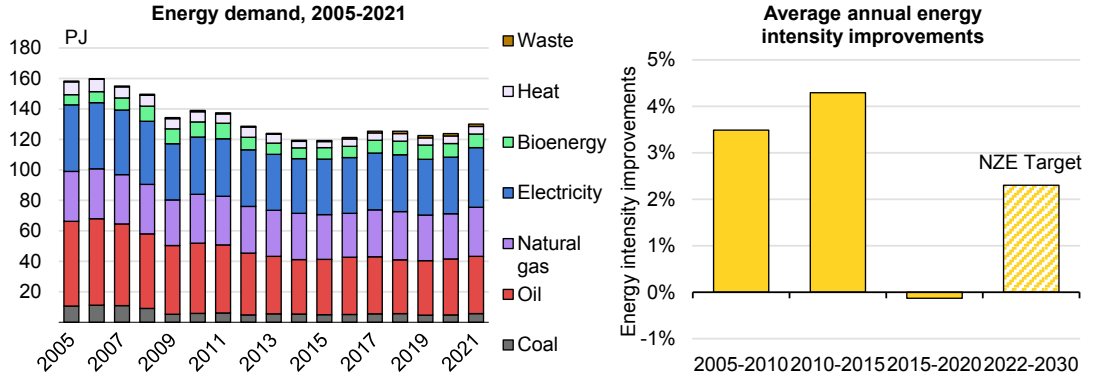
The Climate Agreement also introduced CCS as an important mechanism for achieving climate neutrality by alleviating emissions that are otherwise extraordinarily difficult or expensive to avoid while also providing negative emissions by capturing and storing biogenic emissions. The agreement allocated DKK 16 billion for CCUS, with the first subsidies to be awarded in 2023. The first tender and CO_2 storage licence were awarded in 2023.

Energy use and emissions

Industry, accounting for 23% of Denmark's energy consumption (130 PJ), is the sector with the lowest TFEC. From 2010 to 2020, the sector's energy consumption decreased by 11%, yet increased by 5% from 2020 to 2021. Industry accounted for 25% of total energy-related GHG emissions. Emissions in the sector decreased by 26% from 2005 to 2021. In 2020, the main energy source in industry in Denmark was electricity, accounting for 30% of energy consumption, slightly higher than the share of oil at 29% (a very high share compared to the IEA average of 15%), natural gas at 25%, bioenergy and waste at 8%, coal at 4.3%, and district heat at 4%. During the period between 2010 and 2021, the industry sector reduced the use of all energy sources, but mainly district heat (-24%) and oil (-18%). After an 18% decrease from 2010 to 2020, coal consumption increased 17% in 2022, back to the 2010 level. Industrial energy efficiency in Denmark improved from 2005 to 2015. However, between 2015 and 2020, the average annual energy intensity improvement rate in industry (measured as compounded annual growth rate of industry

TFEC/GDP) dropped to -0.1%, calling for further efforts in line with the global net zero emissions target. The situation worsened in 2021, as TFEC increased by 5%.

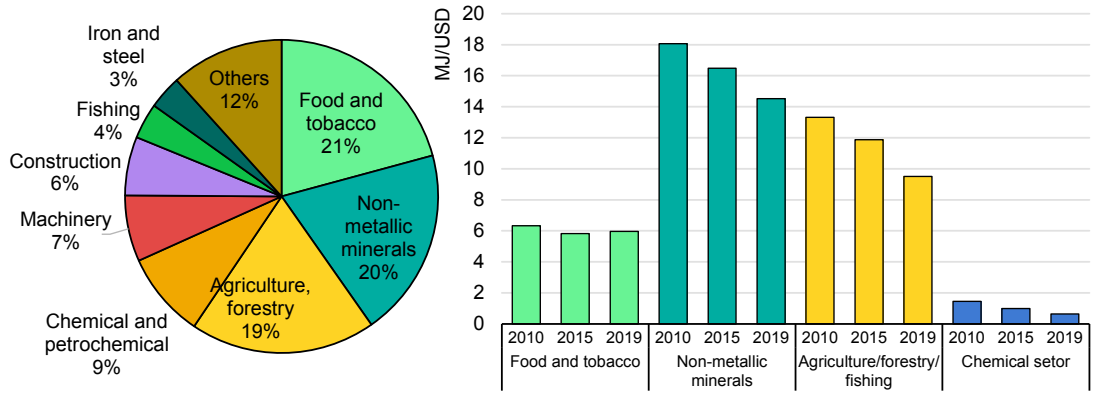
Figure 7.1 TFEC in industry in Denmark by source (2005-2021) and average annual energy intensity improvements in the industry sector (2005-2020) and targets (2022-2030)



Sources: IEA (2023), World Energy Balances; IEA (2023), World Energy Outlook 2023 Extended Dataset.

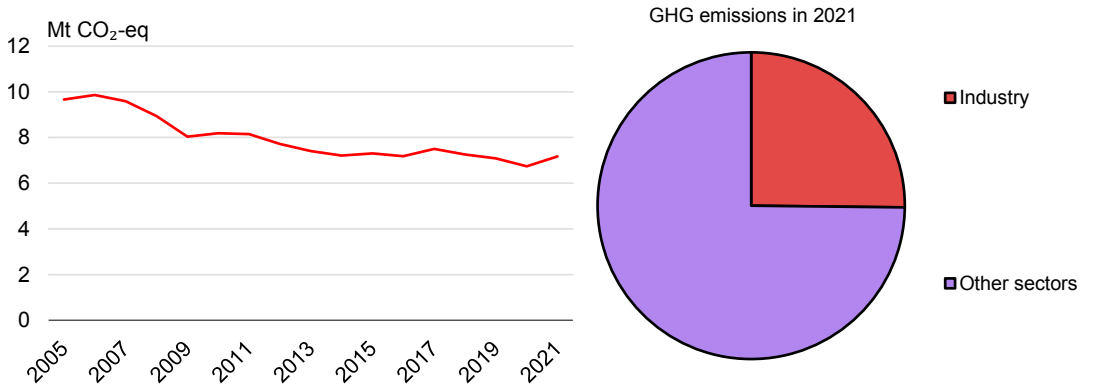
The main industrial subsectors in Denmark are food and tobacco (22%), non-metallic minerals, such as cement and clinker production (20%), agriculture/forestry (19%), and chemical and petrochemical (9%). Together these subsectors account for two-thirds of industry's TFEC (Figure 7.2). In terms of energy intensity per value added, the chemical sector has achieved important efficiency gains, decreasing its energy intensity by 58% from 2010 to 2020. The energy intensities of non-metallic minerals, food and tobacco, and agriculture/forestry/fishing sectors also decreased during the same period, by 5%, 17% and 23%, respectively.

Figure 7.2 Total final energy consumption in industry by subsector (2021), and energy intensity per value added (2019)



Source: IEA (2022), Energy Efficiency 2022.

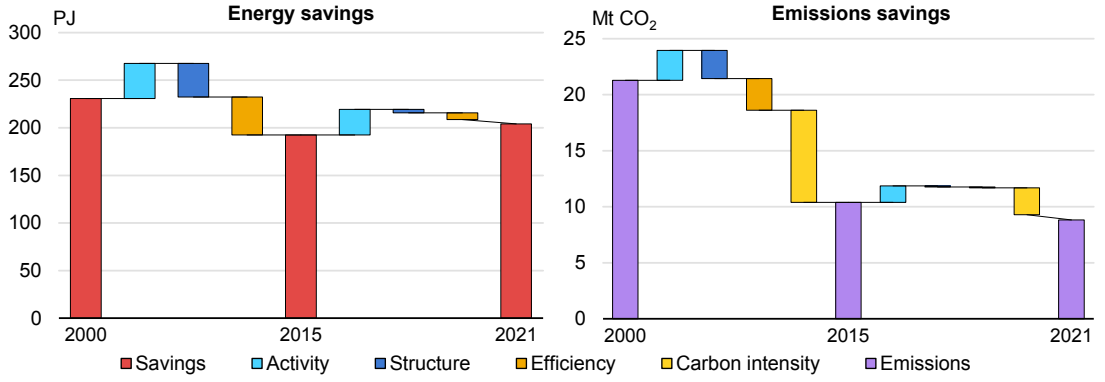
Figure 7.3 Energy-related greenhouse gas emissions in industry in Denmark, 2005-2021



Source: IEA (2023), Greenhouse Gas Emissions from Energy.

Denmark's industrial efficiency has largely remained stable over the past decades, while its emissions have seen a stark reduction (Figure 7.4), mainly due to fuel switching from coal to gas and bioenergy.

Figure 7.4 Industry's and services' estimated cumulative energy and emissions savings broken down by activity, structural change and energy intensity in Denmark, 2000-2021



Source: IEA (2023), Energy End-uses and Efficiency Indicators.

Policies and measures in industry

Carbon pricing and taxation

In June 2022, the Danish government decided to increase carbon taxation for industry and transport. Tax rates will be set at 100 EUR/t CO_2 for companies outside the EU ETS, 50 EUR/t CO_2 for companies within the ETS, and 13 EUR/t CO_2 for mineralogical and metallurgical processes. The tax will be phased in from 2025, when it will be 350 DKK/t CO_2 for non-ETS businesses and increase by DKK 80 annually until 2030. For ETS businesses, it will be 75 DKK/t CO_2 and increase by DKK 60 annually until 2030. For businesses with mineralogical processes, the tax will be 100 DKK/t CO_2 in 2025, with an annual increase of DKK 5 through 2030.

Energy efficiency measures

To increase awareness of energy efficiency improvement options, the website SparEnergi.dk includes tips on how to reduce energy consumption in corporations. The DEA collects data from mandatory energy audits of non-SMEs, in line with the EED requirement for audits at least every four years. This includes energy consumption and energy savings potential (including life cycle cost analysis for projects) in the enterprise.

In 2023, the DEA mapped the energy consumption of 42 industries in the manufacturing, agriculture and construction sectors, to estimate their savings potential. The study shows how much energy companies can save by using waste heat and by electrifying. For instance, it is said that 10% of total energy consumption could be saved by making investments that pay for themselves within four years. Process plants could be optimised with the use of heat pumps and by using waste heat. Waste heat leads to energy savings of 25-30% of heat consumption. In addition, half of industries' energy consumption could be cut by electrifying their processes.

An energy efficiency obligation scheme was in place in Denmark until 2020, when it was not renewed. The scheme was partially replaced by the enterprise scheme, a scheme for energy efficiency improvements and the conversion of private companies' consumption. Following an adjustment in November 2022, the scheme now provides a fixed amount per kWh saved, or DKK 500 per saved t CO_2. The grant covers up to 50% of the cost of an energy-saving or CO_2 reduction project, with a maximum grant of DKK 112 million. Examples of projects that can receive grants include replacing boilers with heat pumps (up to 1 000 kW), establishing heat recovery systems and energy optimisation of process plants. The scheme is designed to achieve around 60% of Denmark's energy savings obligation under the EU Energy Efficiency Directive (EED). The enterprise scheme has a budget of DKK 200-600 million each year and a total DKK 3 500 million and is expected to run until 2029.

Climate audits were also introduced for selected enterprises. An additional support scheme is being developed to support the green transition of companies most affected by the increased carbon taxation. The climate audits and support scheme will be implemented from 2025 alongside the carbon taxation.

As of 2022, there were 1 023 non-SMEs in Denmark. According to Article 8 of the EED, these enterprises are obliged to undergo energy audits every four years or obtain an ISO 50001 certification (which includes energy audits). The DEA collects the audit reports and asks companies to submit a document with key data about their energy consumption and energy savings potential.

Denmark also had voluntary agreements with around 120 energy-intensive companies. These agreements were made based on an audit done by a consultant, who identified energy efficiency measures to align the company's performance with ISO 50001 standards with a three- to five-year amortisation rate. In return, the company would receive a tax relief. If the company did not make the agreed-upon investment, it had to pay the tax in full. This scheme came to an end on 31 December 2020. The new, lighter version of voluntary agreements focuses on excess heat and addresses enterprises with surplus heat to be utilised as district heating. The new scheme does not require ISO certification, but it still mandates companies participating in the programme to conduct an energy review every four years.

Assessment

Denmark has set in motion political agreements with the industry sector: the Climate and Industry Agreement and the Green Tax Reform for Industry. The government has adjusted its approach to support industrial decarbonisation, making a stronger push for carbon pricing instruments while adjusting existing subsidy schemes to promote the shift to greater electrification and low-emission heat sources.

Denmark's leading energy efficiency obligation schemes and voluntary end-use reduction agreements have supported a strong reduction in energy use and in the use of fossil fuels, with manufacturing end use having halved over the past decade. While Denmark has had energy efficiency policies in place for industry for decades, a large potential remains, notably in small and medium-sized enterprises (SMEs), according to the DEA's latest mapping. Industry still accounted for 25% of energy-related GHG emissions.

In 2020, the DEA adopted an enterprise scheme to partially replace the existing energy efficiency obligation schemes. The scheme is designed to achieve about 60% of Denmark's current EED energy savings obligation. To accelerate companies' participation, the scheme was revised to take a fixed-rate approach instead of an auction-based approach, with applications being prioritised on a first-come, first-served basis. With a budget of DKK 3.5 billion (about USD 520 million), the scheme will run until 2029.

Denmark also used to have voluntary energy use reduction agreements – through a tax refund – with 120 energy-intensive companies, mainly SMEs, but this scheme also ended in 2020. A new, lighter version of voluntary agreements – with tax exemption for surplus heat – focuses on enterprises with surplus heat to be utilised as district heating. The new scheme does not require ISO certification, but still mandates companies participating in the programme to conduct an energy review every four years. The companies are, however, not obliged to follow the advice from the review.

In response to recent gas price increases, the industrial sector has shifted some demand to oil. Continued availability of climate and energy audits would help to identify and implement cost-effective opportunities for electrification and low-emission fuels.

Recommendations

The government of Denmark should:

- Work with industry on dedicated decarbonisation strategies that integrate material efficiency approaches, energy efficiency, renewables, waste heat utilisation and circular economy, as well as energy technology and innovation efforts.
- Based on the mapping of energy efficiency potential, expand measures for less energy-intensive industries, including small and medium-sized enterprises, to raise their capability to use their potential for energy efficiency and shift to low-emission heat.
- Ensure the availability of skilled energy auditors to support industry to identify and implement energy efficiency improvements.
- Incentivise data centres to connect to the heating networks to valorise surplus heat.

8. Energy research, development and demonstration

Key data (2021)

Government energy RD&D spending: USD 195 million

Share of public energy RD&D spending in GDP (2020): 0.046%

Private sector energy RD&D spending: USD 347.88 million

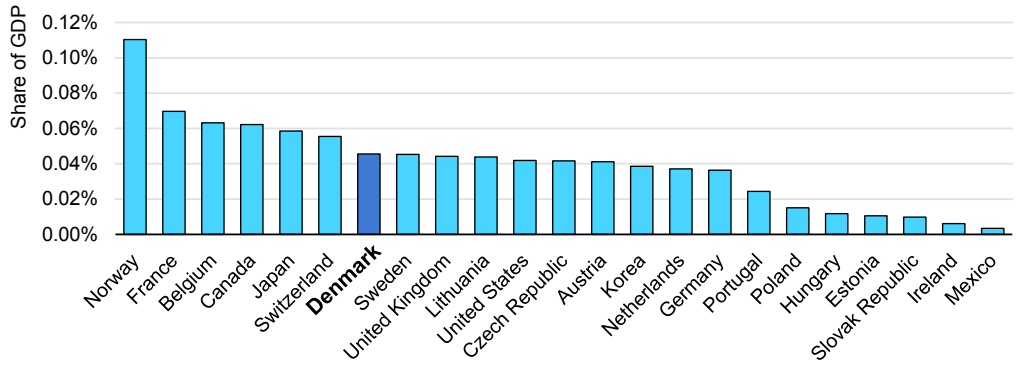
Share of private energy RD&D spending in GDP: 0.096%

Exchange rate: DKK 1 = USD 0.14 = EUR 0.13

Overview

In 2020, Denmark had the seventh-highest energy-related public RD&D spending per GDP among IEA member countries, after Norway, France, Belgium, Canada, Japan and Switzerland (Figure 8.1).

Figure 8.1 Energy-related public RD&D spending per GDP in IEA countries, 2020



Source: IEA (2022), IEA Energy Technology RD&D.

Energy RD&D priorities and strategies

The Danish government considers energy technology and innovation to be a key driver for meeting Denmark's climate and energy targets, notably the emissions reduction goal of -70% by 2030. Energy innovation is at the heart of the national strategy for investments in green research, technology and innovation presented in 2020. It lays down the framework for accelerating the development of new green solutions and technology to reduce costs and enable CO_2 reductions in Denmark and abroad by 2030 and 2050. The strategy was elaborated based on a broad stakeholder consultation. The Danish strategy identifies seven priorities for Denmark's long-term research needs: 1) energy production; 2) energy efficiency; 3) agriculture and food production; 4) transportation; 5) environment and the circular economy; 6) nature and biodiversity; and 7) sustainable behaviour.

These seven political priorities for green research and innovation are implemented across four missions as partnerships for Denmark's green research and innovation efforts:

- 1. carbon capture and storage or utilisation
- 2. green fuels for transportation and industry (Power-to-X)
- 3. climate and environmentally friendly agriculture and food production
- 4. recycling and reducing plastic waste.

Key actors in the energy innovation ecosystem

Under the overall lead of the Ministry for Higher Education and Science, several ministries collaborate on energy RD&D: the Ministry of Industry, Business and Financial Affairs; the Ministry of Climate, Energy and Utilities; and the Ministry of Foreign Affairs.

Resource push

In 2021, the Danish government provided around USD 109 million for all four missions under the green investment strategy. The Danish Green Research Strategy aims at maintaining green research funds at the 2020 level from 2021 to 2025 (EUR 310 million).

The Danish National Research Foundation has an annual budget of DKK 0.5 billion (USD 72 million) to support basic research, but there is no dedicated energy programme as calls are organised competitively. The Independent Research Fund Denmark and Innovation Fund Denmark have some funds earmarked for green research (not energy RD&D). Out of the Independent Research Fund's total budget (DKK 1.5 billion), DKK 0.1 billion (USD 14 million) is earmarked for green research. Under the Innovation Fund Denmark (DKK 1.7 billion), earmarked green research amounts to USD 100 million. Three development and demonstration programmes allocated DKK 0.9 billion (USD 130 million) to the energy sector, with the Energy Technology Development and Demonstration Program (EUDP) allocating DKK 0.5 billion alone.

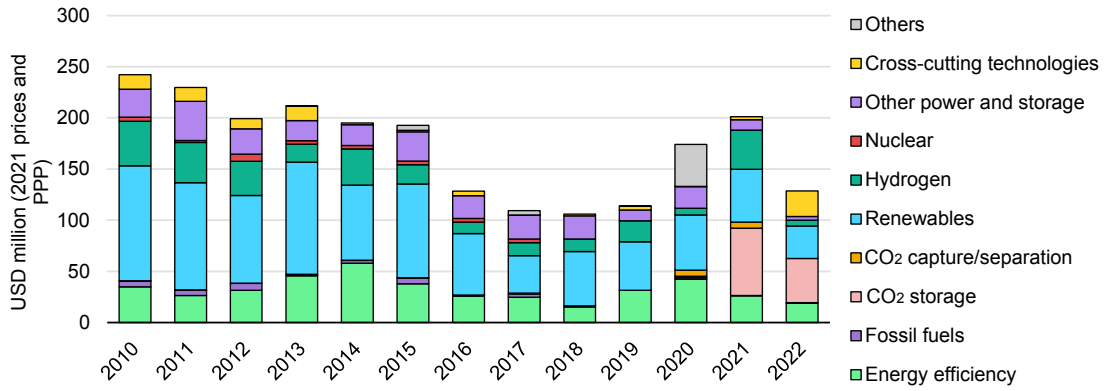
Besides public funding, private foundations, EU funding (EU Horizon Europe) and public foundations together contributed to a total public funding envelope of EUR 618 million for green research and innovation projects. Private foundations have become an important

source of funding for green research. The Novo Nordisk Foundation granted DKK 1.2 billion (USD 170 million) in 2021.

Public spending on energy RD&D

In 2022, Denmark's public budget on energy-related RD&D was USD 128 million, 4% lower than in 2010 (USD 242 million) and 36% lower than in 2021 (USD 201 million). In 2022, CCS accounted for the largest share (34%) of the public budget on energy-related RD&D, followed by renewables (25%), energy efficiency (15%) and cross-cutting technologies (19%). Out of the total energy-related RD&D public budget on fossil fuels of USD 44 million, 98% was directed to CO_2 storage; the remainder was directed to oil and gas. Hydrogen and other power and storage accounted for 4.4% and 2.9% of the RD&D energy-related budget respectively.

Figure 8.2 Energy-related public RD&D budget by sector in Denmark, 2010-2021



Source: IEA (2023), IEA Energy Technology RD&D.

Energy RD&D funding programmes

The main public funding programmes are disaggregated by technology readiness levels (TRL): the Danish Innovation Fund supports TRL 1-3, the EUDP funds TRL 4-8, and the Export and Investment Fund supports TRL 9.

Led by an independent board appointed by the government, the EUDP is Denmark's central energy funding programme. The DEA acts as secretariat, organising the programme. The EUDP is technology-neutral in its prioritisation and assesses applications according to nine criteria, including their contribution to innovation, climate policy targets and commercialisation. The EUDP programme is funded by the state budget, with an annual research reserve. DKK 500 million (EUR 67 million or USD 73 million) were made available in 2022.

Under the Danish Finance Act, ELFORSK is a state budget fund that supports research and innovation projects that promote energy efficiency and flexibility solutions through data processing, digitisation and sector coupling across electricity, district heating and transport, among others. ELFORSK co-finances projects through its public annual pool of DKK 25 million, which is administered by Green Power Denmark, the Danish business association.

Created in 2022 under the 2020 Finance Act, Denmark's Green Future Fund (DKK 25 billion) supports the development, demonstration/commercialisation and global export of new technologies. Its priorities are converting energy systems to renewable energy, storage and efficient use of energy. The Green Future Fund invests in technology development through the Vaekstfonden, the state's investment fund, in demonstration under the Danish Green Investment Fund, and in export through the Export Credit Agency and the Investment Fund for Developing Countries.

Box 8.1 Denmark's energy R&D priority projects

Carbon capture, utilisation and storage

Denmark invests in the carbon capture, utilisation and storage (CCUS) value chain as a key technology for meeting its climate neutrality goals. With the support of the Danish parliament, a pool of companies was formed to promote CCUS and is expected to start investments in 2024. The total amount of funding from the pool is expected to reach EUR 109.5 million per year. On the capture side, the first pilot plant, the Amager Resource Centre, was established in 2021 in Copenhagen. Designed as a waste-to-energy facility, it is used to test and find the cheapest carbon capture technologies by focusing on energy optimisation. A demonstration plant was planned to be built to capture 500 kg of CO_2 per hour. Denmark has identified potential for storage across its territory. Regions like Hanstholm, Thisted, Syddanmark, Olie-gasfelter and Skagerrak have CO_2 storage capacities above 1 000 million tonnes (Mt). Companies such as Gas Storage Denmark can permanently store 500 000 tonnes of carbon dioxide (t CO_2) every year from 2025 in their facility in Zealand. INEOS Energy will inject CO_2 into an existing well 150 km from Jutland as part of the Greensand project, which has plans to store up to 8 Mt CO_2 per year starting in 2030. Project Bifrost offers a similar solution to store 3 Mt CO_2 in existing gas field infrastructure off Jutland. Denmark is advancing in CO_2 transport. Evergas and Ultragas, two Danish shipping companies, established the world's first CO_2 shipping entity (Dan-Unity CO_2).

PtX Strategy – Hydrogen

Green Fuels for Denmark aims to produce 275 000 tonnes of e-fuels annually by 2030 for use in aviation and other hard-to-abate sectors. Denmark plans to be able to completely supply domestic fuel demand for aviation by 2027. The European Commission recognised this project as an Important Project of Common European Interest. The Power-to-X (PtX) Strategy focuses on using CO_2 to create green hydrogen solutions. Owned by the Ministry of Finance, Evida originally distributed methane gas, but has been nominated to support PtX and CCUS by reusing their pipelines for CO_2 and hydrogen transport and distribution.

Circular economy

Producing wind turbine blades manufactured with epoxy-based resin has been standard practice in the wind industry. In many mature markets for wind energy, the first turbines are now reaching the end of their operational lifetime. Current practice is that blades end up in landfills. Danish wind turbine producer Vestas announced in February 2023 an innovation to reuse wind turbine blades. Once matured, this technology has the potential

to eliminate the need for landfill disposal of retired blades with no need to redesign blades by reusing materials from blades currently in operation in two production steps. The first step separates the glass fibres, carbon fibres and epoxy while the second step dissolves the epoxy into chemical components, making it possible to produce new epoxy. The chemicals used are widely available and rather inexpensive. Taking this innovation to the market will require upscaling.

Knowledge management

Denmark has strong public-private partnerships and innovation centres, building on the excellency of its leading universities and strong Danish industry players, including start-ups. Key technology missions are carried out through multiannual green partnerships of academia, business partners, public authorities and private players.

Leading examples for energy are the missions on CCUS and PtX. There is a strong interaction with universities and business, which is a success factor for Denmark. The government uses formal "agreements" with industries to support such public-private partnerships. The Climate Agreement for Energy and Industry of June 2020 is an example.

For example, there are about 70 companies operating in the PtX and CCUS area in Denmark, working with project development, research, technology development, consulting, production equipment, and operation and maintenance. The value chain for PtX is larger, however, and includes other actors such as wind turbine manufacturers; plant owners and developers; producers of electrolysis and synthesis plants; suppliers of hydrogen infrastructure; and consumers of green fuels in sectors such as shipping, aviation and heavy road transport.

International co-operation

Denmark is a very active international partner in energy technology and innovation, building on its innovation leadership, for instance in offshore wind technology and energy efficiency. Denmark looks to build future industrial leadership and global partnerships and aims at more integrated research planning and strategies with programmes in the EU (Horizon Europe) and internationally to increase the inflow of funds to Denmark.

At a global level, Denmark's knowledge partners participate in 18 IEA Technology Collaboration Programmes, with a strong focus on energy systems and sector coupling/integration, including energy technology systems analysis, end-use sectors (buildings and transport), smart grids, energy storage, bioenergy, heating/cooling renewable energy, and hydrogen.

Denmark participates in Mission Innovation 2.0: it co-leads the Zero-Emission Shipping Mission with Norway and the United States and is part of several industry-focused technology missions – Green Powered Future, Clean Hydrogen, Carbon Dioxide Removal, Urban Transitions, Net-Zero Industries and Integrated Biorefineries. Denmark is also well represented in Horizon Europe and involved in many international research programmes,

R&D bodies and platforms including SET-Plan, IEA/CERT, Nordic Energy Research, the Clean Energy Ministerial and, as mentioned above, IEA Technology Collaboration Programmes.

Figure 8.3 Denmark's key areas of international technology collaboration

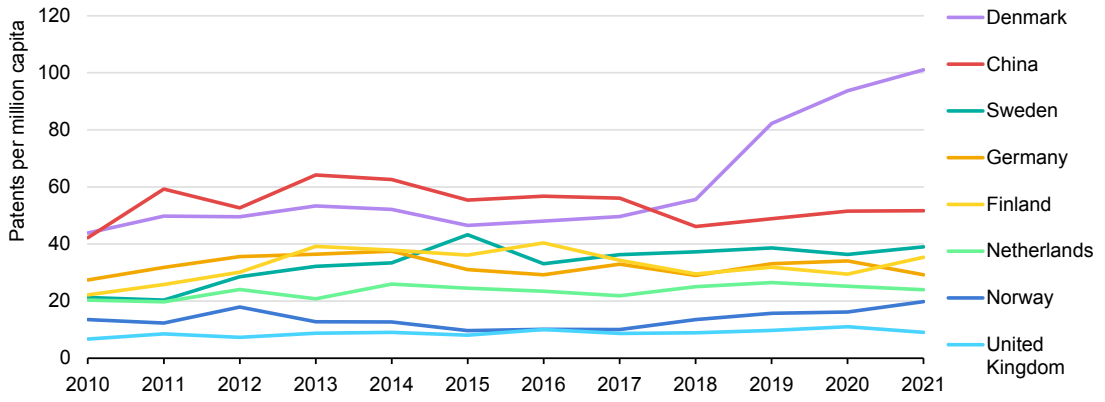
Note: S&T = science and technology; IFD = Innovationsfonden; EUDP = Energy Technology Development and Demonstration Program; EU = European Union.

Source: Denmark, Ministry of Higher Education and Science Division of Research, Innovation and International Cooperation.

Market pull

Denmark does not have innovation tax credits, but high energy and carbon taxes are considered to be important drivers for private sector innovation and investment in energy RD&D. Energy RD&D is also promoted through green public procurement. Denmark uses 7 government-approved technological service organisations which deliver technological services to 16 000 Danish companies and 1 000 public customers a year.

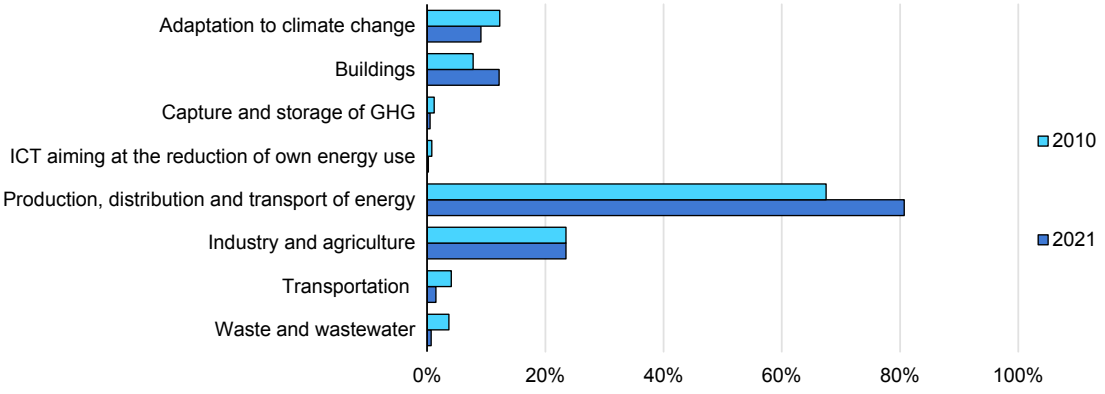
Figure 8.4 Patent applications in technologies for mitigation/adaptation against climate change, 2010-2021



Source: IEA analysis based on data from Denmark, Ministry of Higher Education and Science.

Denmark is among the countries with the most applications per capita to the European Patent Office (Figure 8.4). The level of applications increased dramatically in 2019. Denmark is specialised in patents related to the production, distribution and transport of energy (Y02E). In 2021, more than 80% of patents were in this area (Figure 8.5).

Figure 8.5 Distribution of patents across subgroups in Denmark, 2010 and 2021



Note: Sum across subgroups can be higher than 100% since a patent can be in more than one technological area.

Source: IEA analysis based on data from Denmark, Ministry of Higher Education and Science.

Monitoring, evaluation and tracking

The Green RD&D Strategy mandated the Ministry of Higher Education and Science to co-ordinate the monitoring of results, involving experts from the universities. Individual funds are evaluated over time. For instance, the main energy sector funding programme (EUDP) has supported more than 1 000 innovative projects with about DKK 5.7 billion since its creation.

Assessment

Since the IEA's last review in 2017, Denmark presented a first dedicated green RD&D strategy in September 2020, one of the main recommendations of the 2017 review. The strategy is the basis for prioritising RD&I investments in energy by identifying key research needs of relevance to the Danish energy system and aligned with the energy and climate agreements, such as CCUS, hydrogen and e-fuels, the integration of renewables, and energy-efficient buildings and renovation.

The strategy fully reflects and supports the country's energy and climate priorities through its four green missions or partnerships: green fuels for transport and industry; CCUS; climate- and environmentally friendly agriculture and food production; and the circular economy. The seven green action areas include energy production – PtX and CCUS – energy efficiency and transport.

In 2021, Denmark's public budget on energy-related RD&D was USD 195 million, 16% lower than in 2010 (USD 232 million). The current spending level is not yet consistent with the government's goal of maintaining 2010 spending levels. However, Danish industry is spending twice as much of the public funding amount, showing excellent leverage of public funding.

By international comparison, Denmark ranked seventh for the share of public energy RD&D funding in GDP (0.046%) after Norway, France, Belgium, Canada, Japan and Switzerland. To meet its high climate and energy targets for 2030 and 2045, a sustained spending level is recommended after 2025 for the energy research ecosystem to plan ahead.

In 2021, energy production received the most RD&I funds, while energy efficiency ranked fourth (out of seven sectors). Fossil fuels accounted for the largest share (36%) of energy-related RD&D public spending: around 92% of the fossil fuel budget was directed towards CO_2 storage, the rest was for CO_2 capture (8.2%) and oil and gas (0.2%). The remainder of the public funding was directed towards renewables (26%), hydrogen (19%) and energy efficiency (13%).

The EUDP is Denmark's main energy funding programme. The DEA acts as secretariat. Overall, Innovation Fund Denmark and the Independent Research Fund Denmark have earmarked annually green funding envelopes. Private foundations, such as Novo Nordisk Fonden or Innovationsfonden (IFD), have become an important source of funding of energy RD&I.

While funding programmes target different TRL levels, there are overlaps across the full innovation cycle due to separate funding strategies. Greater co-ordination across government would be useful in the implementation and review of the green research strategy. There is no formal institutional co-ordination of energy RD&D programmes or missions across government according to the European Commission's latest review. The annual earmarking does not provide visibility of funding budgets for project promoters.

With regard to patents, Danish companies took out 551 green patents at the European Patent Office in 2021, which corresponds to 93 green patents per million inhabitants, placing Denmark in the first position in front of Switzerland, Finland and Sweden. According to data from the US Patent Office, Denmark ranks first, followed by Switzerland, Japan, Korea and the United States.

A stated objective of the new RD&I strategy is to enhance the green frontrunner position of Danish industries to the benefit of exports and green jobs in Denmark. In 2021, Denmark's export of energy technology and services was DKK 105.2 billion, almost the same level as in 2020, but 14.7% lower than the 2019 pre-Covid level. Exports of energy technology accounted for 11.3% of total Danish merchandise exports in 2021, which is a decline compared to 2020 of 0.8 percentage points.

Building on its strong green RD&I base, Denmark has many start-ups in environmental technology. However, it appears that while start-ups have a larger than average employment footprint, the scale-ups face particular difficulties, according to the OECD.

Denmark has the fourth-largest domestic material consumption in the European Union (measuring the total amount of materials directly used by an economy and defined as the annual quantity of raw materials extracted from the domestic territory + all physical imports – all physical exports). A strategic approach to critical raw materials, notably rare earth materials and other minerals and metals, will be of key importance for the development of Danish export products, clean energy technologies generation equipment (solar PV, wind turbines, storage, energy-efficient lighting), electric mobility and digital technologies. The government should carry out a supply chain risk assessment, mapping consumption, waste management, recovery and recycling and assessing the substitution potential and the material efficiency/eco-design.

Recommendations

The government of Denmark should:

- Support the co-ordination of funding programmes through the annual mapping across sectors and technology readiness levels to avoid both overlap and gaps in funding.
- Sustain a stable funding framework with green research, development and innovation earmarking, well ahead of the 2025 end of funding, based on a mid-term evaluation.
- Translate Denmark's export ambition ("green frontrunner") into sustained investment in RD&I, including for early-stage demonstration and green start-ups/scale-ups.
- Support global leadership on sustainable behaviour and social consequences and increase green research, development and innovation funding in this area to identify partners and collaboration.
- Expand the circular economy research and innovation focus to the recycling of batteries and retaining critical minerals, material substitution, and improved eco-design, critically important for Denmark's exports, notably electric power generation equipment.

9. Electricity

Key data (2022)

Electricity generation: 35 TWh (wind 54%, bioenergy and waste 23%, coal 13%, solar 6.3%, natural gas 2.9%, oil 0.9%); -1% since 2011

Electricity net imports: 2.76 TWh (imports 10.31 TWh, exports 7.54 TWh)

Electricity consumption: 32 TWh (industry 36%, residential buildings 31%, services sector buildings 30%, transport 2.9%); +1% since 2011

Peak load (2020): 5.8 GW

Installed capacity (2021): 16.6 GW

Overview

Denmark is among the global leaders in the power system integration of variable renewable energy from solar and wind with a share of 60% in 2022. Wind energy alone reached a share of 54% in 2022, the highest share of wind in its electricity mix among IEA countries. Denmark is well interconnected and integrated in the regional power markets, the Nordic market and the continental European system.

Thanks to the rise of wind generation, the role of coal and gas has been in fast decline in recent years, making Denmark's electricity generation low carbon with just above 90 g CO_2/kWh in 2022. This is a good starting point for further electrification.

By 2030, Denmark has the stated goal of quadrupling electricity production from solar and onshore wind, adding another 50 TWh. The resulting doubling of its power generation from variable renewable energy puts pressure on the whole system unless Denmark shifts to the next stage of energy system integration (see Chapter 10) with the electrification of the transport and heating sectors. The government already has strategies and plans for PtX and sector integration.

In only eight years, Denmark is expected to become an exporter of electricity. There will be a large spread between production and consumption both over geography and over time. Electricity grids need to be adapted and consumption needs to become more flexible to maintain grid stability. Denmark will need to lead on the future market design, including at the regional level, supportive of a very high level of renewable energy integration.

Electricity generation, demand and trade

Installed generating capacity

In 2021, Denmark's total electricity generation capacity, excluding distributed generation, was 16.55 GW. Fossil fuels accounted for 31% of total installed capacity. Installed capacity of wind reached 42% and solar 12%, while hydro remained stable at 0.05%. Wind capacity has doubled since 2005 and solar has almost tripled since 2012. On the other hand, fossil fuel capacity has been slowly declining, from almost 10 GW in 2005 to 8.4 GW in 2013, 7.9 GW in 2020 and 5.1 GW in 2021.

Table 9.1 Installed generating capacity, Denmark, 2017-2021

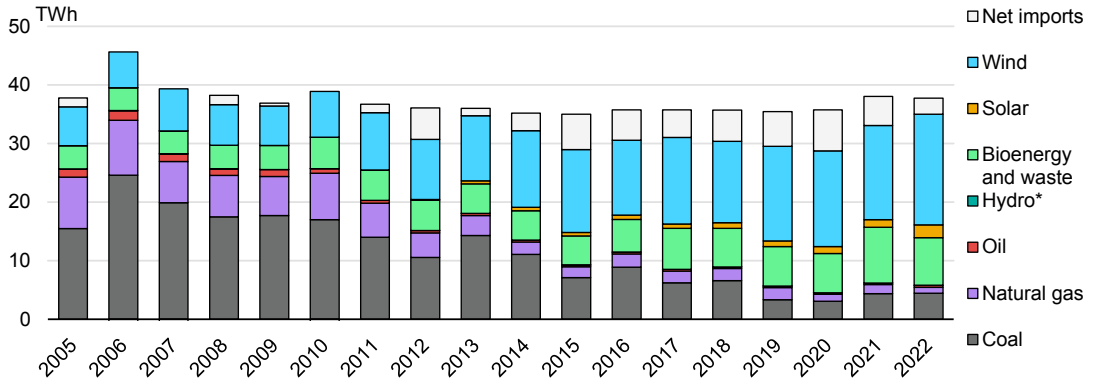
Year/ fuel	Coal	Oil	Natural gas	Waste	Biomass	Biogas	Onshore wind	Offshore wind	Solar PV	Hydro	Total
2017	2.68	1.13	2.04	0.37	1.52	0.11	4.23	1.26	0.91	0.01	14.26
2018	2.68	1.12	1.98	0.37	1.53	0.12	4.42	1.70	1.00	0.01	14.93
2019	2.61	1.13	1.93	0.36	1.72	0.13	4.41	1.70	1.09	0.01	15.09
2020	2.27	1.10	1.93	0.35	1.81	0.13	4.57	1.70	1.33	0.01	15.20
2021	2.24	1.08	1.84	0.35	1.86	0.14	4.72	2.31	2.00	0.01	16.55

Source: Danish Energy Agency (2023), Climate Status Outlook.

Generation

Denmark's annual electricity production was 35 TWh in 2022 (Figure 9.1). Electricity production peaked at 45.6 TWh in 2006 and has been slowly decreasing since. After a slight rebound in 2021, electricity production decreased following high prices due to a lack of precipitation for the Nordic hydro systems and intense economic activity post-Covid. The share of renewables in electricity generation slightly dropped in 2021 due to the temporary increase of coal use in electricity generation that exceeded the increase of generation from biomass.

Figure 9.1 Electricity generation by source and net imports in Denmark, 2005-2022



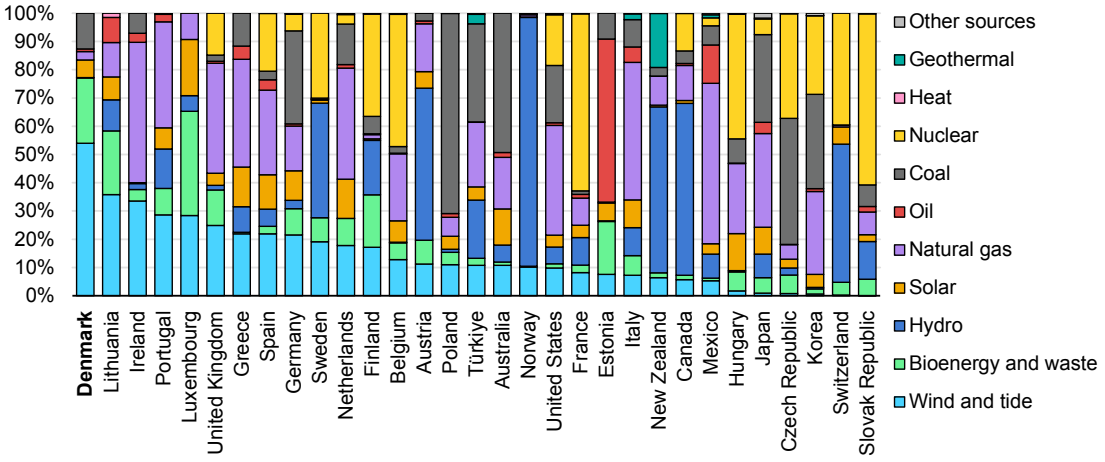
* Hydro is not visible on this scale and represented 0.02 TWh in 2022.

Source: IEA (2023), World Energy Balances.

Overall, fossil fuel use for electricity generation has been largely replaced by renewables. In 2022, renewables accounted for 81% of electricity generation, a major increase from 27% in 2005. In 2022, wind represented 19 TWh, bioenergy and waste 8.1 TWh, solar 2.2. TWh, and hydro 0.02 TWh. Coal has been historically the main fossil source of electricity generation, accounting for 15.4 TWh in 2005, but accounted for only 4.4 TWh in 2022, the equivalent of a 71% decrease. Yet, there was a 45% rebound of the use of coal for electricity generation from 2020 to 2022. Over the 2005-22 period, natural gas decreased by 76% and oil by 88%, representing respectively 1.0 TWh and 0.3 TWh in 2021. There was a 30% rebound in gas use for electricity generation from 2020 to 2021, but the electricity generated from gas reached its lowest point ever in 2022.

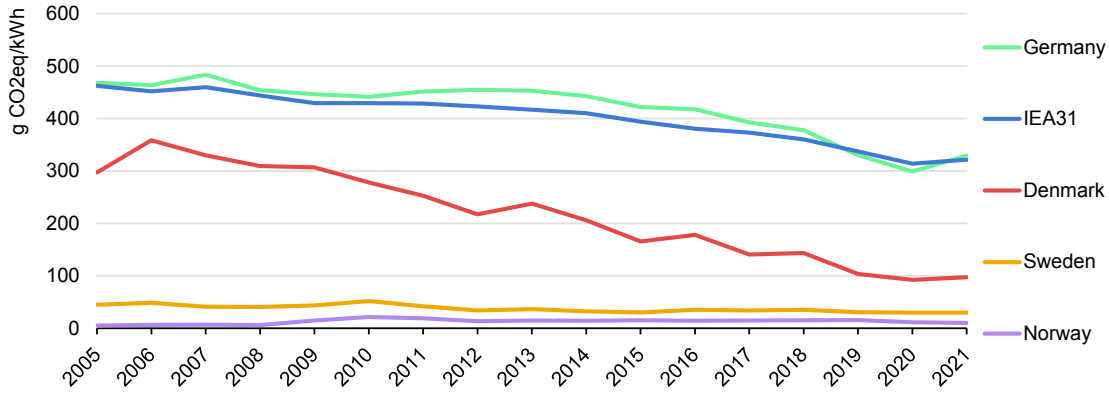
Denmark has the highest share of wind in electricity generation (54%) of all IEA member countries, well above the IEA average of 13% (Figure 9.2). Thanks to the strong renewables growth, Denmark has seen a very stark decline in the carbon intensity of its power generation at 92 g CO_2/kWh in 2022 (Figure 9.3).

Figure 9.2 Electricity generation by fuel, IEA countries, 2022



Source: IEA (2023), World Energy Balances.

Figure 9.3 Carbon intensity of electricity generation in Denmark and selected countries, 2005-2022



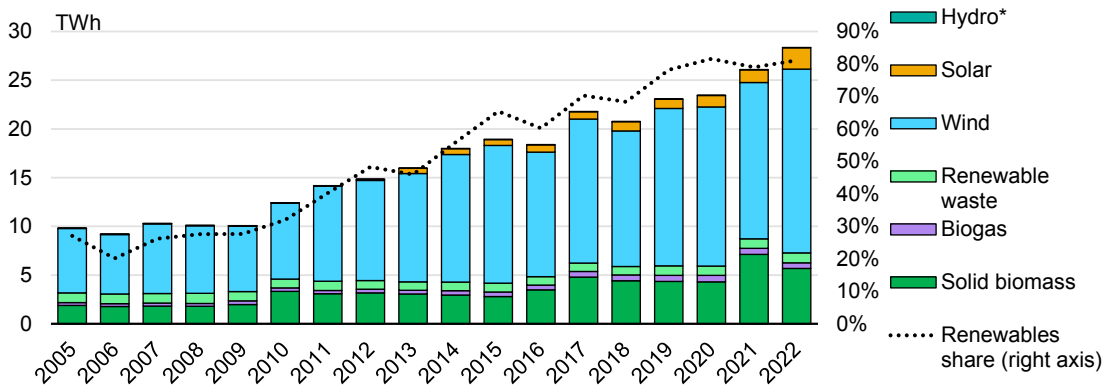
Source: IEA (2023), World Energy Balances.

Renewable generation

Out of the 35 TWh of electricity produced in Denmark in 2022, 81% came from renewable energy sources. The main renewable energy source is wind, followed by solid biomass, solar, renewable waste, biogas and hydro.

Wind production has increased by 143% and solid biomass by 277% since 2005. Solar experienced a tenfold increase over the 2011-21 period, reaching 1.3 TWh in 2021. Biogas has doubled since 2005 and reached 0.6 TWh in 2021. Over the 2005-21 period, hydro was stable at around 0.02 TWh and renewable waste at around 0.9 TWh.

Figure 9.4 Renewable energy in electricity generation in Denmark, 2005-2022



* Hydro represented 0.02 TWh in 2022.

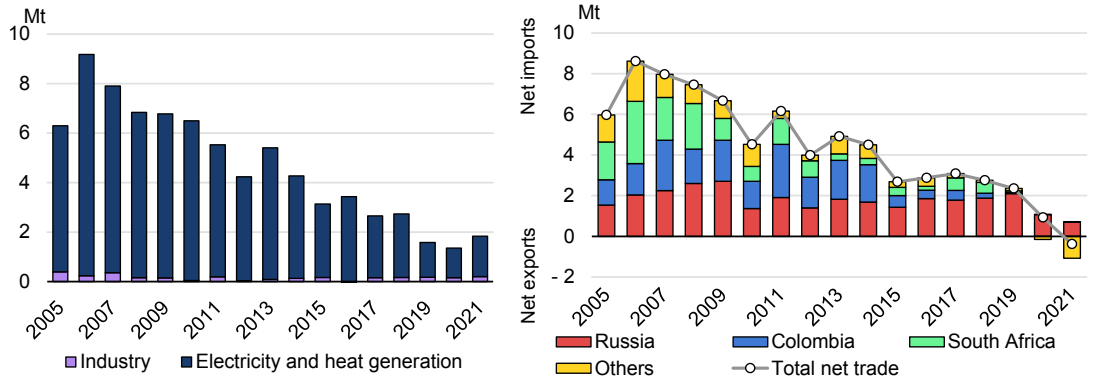
Source: IEA (2023), World Energy Balances.

Coal transition

Despite the slight increase in 2021 compared to 2020, coal use in electricity generation has followed a downward trend since 2006. Coal demand has decreased by 80% since 2005. In 2020, almost all of coal's TFEC was dedicated to electricity and heat generation. Denmark does not produce any coal and covers all its domestic consumption with imports, mainly from Russia, South Africa and Colombia. With the declining use of coal, imports have decreased by 90% since 2005. In 2021, Russia became Denmark's main trading partner. In February 2022, following Russia's invasion of Ukraine, Denmark decided to ban all imports of coal from Russia.

The use of coal for heat and electricity production is expected to be fully phased out in 2028, based on generator's decisions. The government does not provide subsidy schemes for converting from coal to biomass or any other fuel. Ørsted announced the end of coal use in its co-generation plants as of 1 January 2023. The owners of the plants in Odense (Fynsværket) and Aalborg (Nordjyllandsværket) announced decisions to convert the plant to another fuel (Fynsværket to gas) or to close the plant (Nordjyllandsværket in 2028).

Figure 9.5 Denmark's coal demand by sector (left) and total trade (right), 2005-2021



Source: IEA (2022), World Energy Balances.

On 1 October 2022, to ensure security of supply for upcoming winters, Danish authorities ordered Ørsted to postpone the retirement of three thermal plants, including two coal-fired ones, until 30 June 2024. It concerns block 21 of the Kyndby plant (260 MW cooking oil-fired), block 4 of the Studstrup plant (360 MW coal-fired) and block 3 of the Esbjerg plant (370 MW coal-fired).

Table 9.2 Coal power plants in Denmark

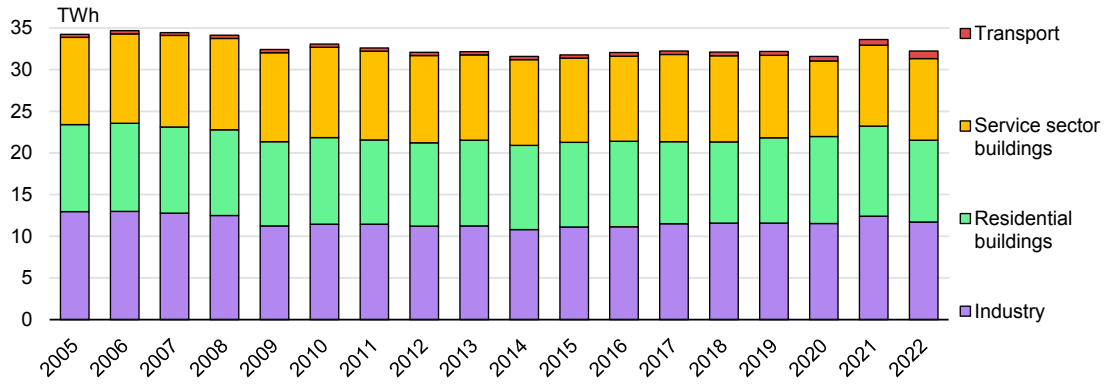
Name	Site	Fuel	Capacity	Commissioning	Operator
Fyn	Odense	Coal, biomass, municipal waste	632 MW	1953	Fjernvarme Fyn A/S
Asnæs	Kalundborg	Coal	1 057 MW	1959	Ørsted
Nordjylland	Aalborg	Coal	741 MW	1977	Aalborg Forsyning
Esbjerg	Esbjerg	Coal	378 MW	1992	Ørsted
Avedøre	Avedøre	Coal, biomass	810 MW	1990	Ørsted

Demand

Electricity demand in Denmark was 32 TWh in 2022 (Figure 9.6). It has remained overall stable at levels around 30-35 TWh, with lower levels during the 2010s.

In 2022, the industrial sector accounted for 36% of the total electricity demand, followed by residential buildings (31%), services sector buildings (30%) and transport (3%). There has been an important uptake of electricity in the transport sector, with demand doubling over the 2005-22 period, albeit from a very low starting point.

Figure 9.6 Electricity demand by sector in Denmark, 2005-2022



Source: IEA (2023), World Energy Balances.

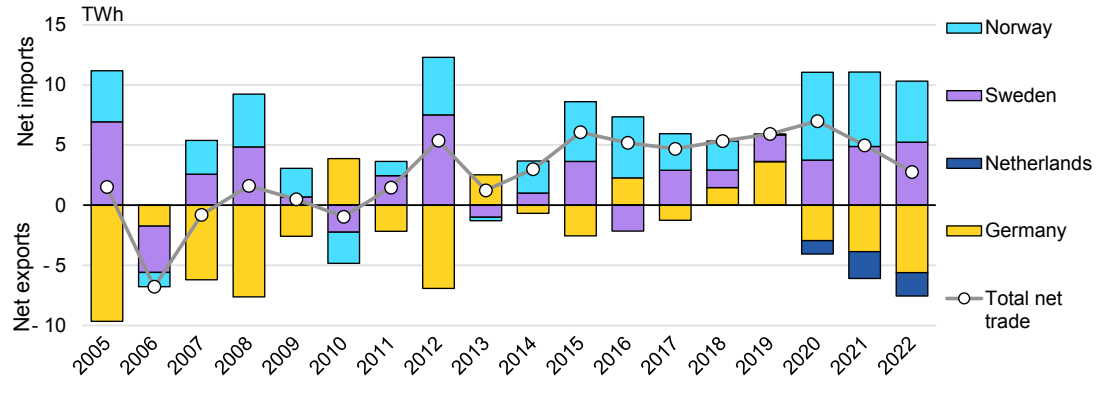
Trade

Over the past 15 years, Denmark has mainly been a net importer of electricity, after having been a net exporter in 2006, 2007 and 2010 (Figure 9.7). Net imports of electricity increased from 2013 to 2015, as coal-fired power generation was phased out, then stabilised at around 5 TWh from 2015 to 2021.

In 2022, Denmark exported 7.5 TWh of electricity to Germany and the Netherlands and imported 10 TWh of electricity from Norway and Sweden.

While Denmark has been a net importer for the last decade, it is expected to turn into a net exporter in the coming years. This is a result of increasing capacities on the interconnectors, the addition of the Viking Link (a 1 400 MW high-voltage direct current [DC] interconnector) connecting Denmark and the United Kingdom, as well as greater deployment of wind power.

Figure 9.7 Denmark's electricity imports and exports, 2005-2022



Source: IEA (2023), World Energy Balances.

Electricity infrastructure

Transmission

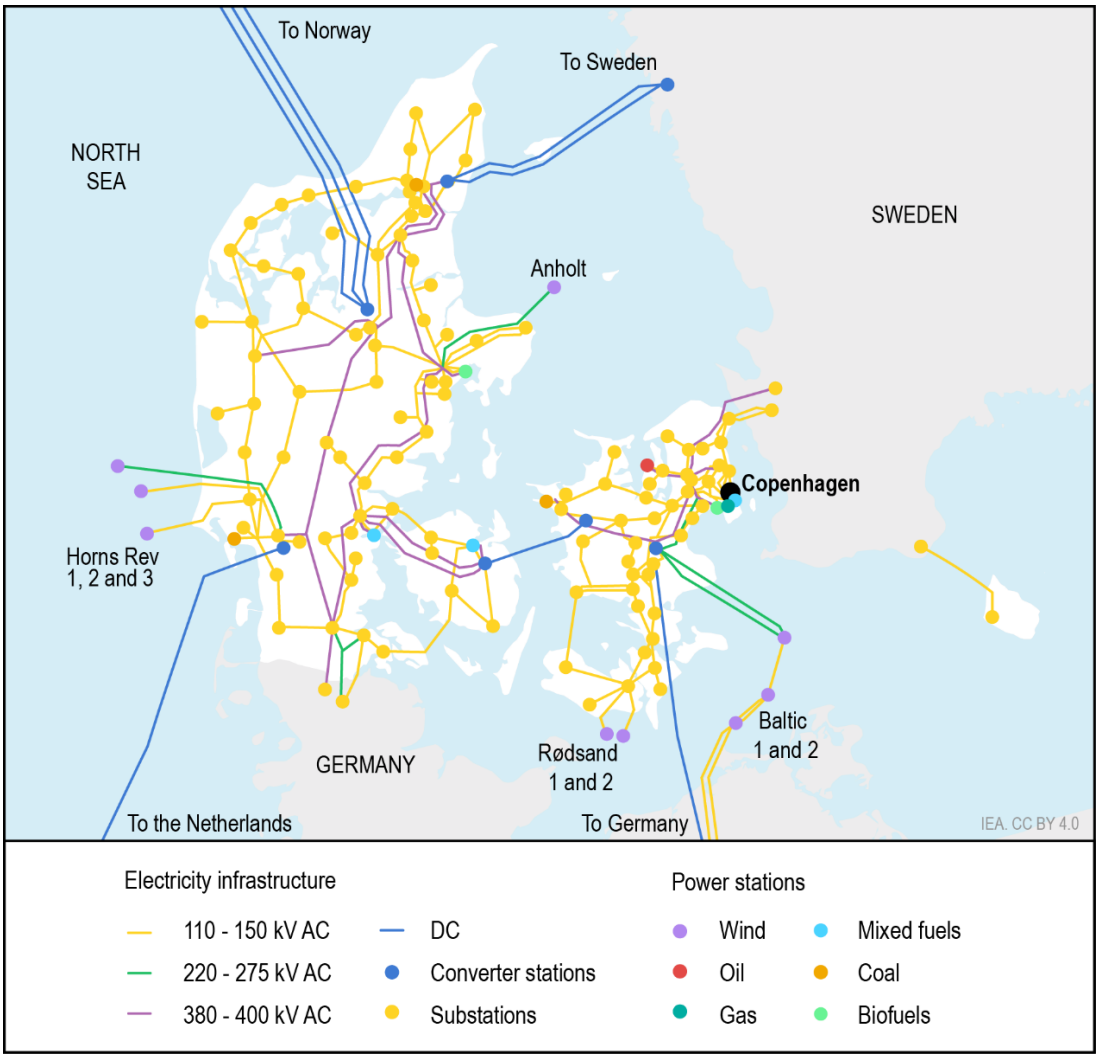
The Danish transmission system is divided into two distinct grids: DK.1, or the western grid, which covers Jutland and Funen; and DK.2, or the eastern grid, covering the islands of Zealand and Bornholm. Energinet is responsible for both grids but they are operationally distinct. DK.1 is synchronised with Germany and the rest of continental Europe while DK.2 is synchronised with Sweden and the rest of the Nordic region. The only direct interconnection between DK.1 and DK.2 is the Great Belt Power Link, a 400 kilovolt (kV) DC line with a capacity of 600 MW.

At the beginning of 2022, the Danish electricity transmission network consisted of approximately 3 000 km of overhead lines and approximately 3 200 km of submarine and underground cables. Underground cabling of the 132 kV and 150 kV grids continues as lifetime on existing overhead lines expire. Energinet, the state-owned transmission system operator (TSO), is responsible for the system operation in Denmark and owns assets operated on voltages above 100 kV. The electricity transmission network in Denmark consists of an alternating current (AC) network at 132 kV, 150 kV, 220 kV and 400 kV levels; a DC connection between Funen and Zealand; and ac and DC connections to neighbouring areas.

Interconnections

Denmark has DC connections to Norway, Sweden and the Netherlands, with a capacity of 1 700 MW, 680 MW/740 MW (export/import capacity) and 700 MW, respectively. There are 400 kV, 220 kV and 150 kV AC connections to Germany with a maximum trading capacity of 1 500 MW northbound and 1 780 MW southbound. The connection from Zealand to Sweden consists of four AC connections with a total market capacity of 1 700 MW/1 300 MW (export/import capacity). From Zealand to Germany, there is one DC connection with a capacity of 600 MW. Several new interconnectors have been commissioned in recent years: the COBRA interconnector linking Denmark to the Netherlands and the new hybrid interconnector via Kriegers Flak to Germany. The Viking Link Cable to Great Britain is under construction and expected to enter into operation in 2023.

Figure 9.8 Electricity infrastructure in Denmark



Notes: kV = kilovolt; AC = alternating current; DC =direct current.

Table 9.3 Interconnectors and their capacity in Denmark

Interconnector	Capacity to DK1 (MW)	Capacity to DK2 (MW)
Jutland to Germany	25 00 MW AC (1 000 MW*)	
Kontek to Germany		600 MW DC
Kriegers Flak to Germany		400 MW DC
Skagerrak to Norway	1 600 MW DC	
Øresund to Sweden		1 400 MW AC
Kontiskan to Sweden	700 MW DC	
COBRA to Netherlands	700 MW DC	
Viking Link to the United Kingdom*	1 400 MW DC	
Storebælt connecting DK1 and DK2	600 MW DC	600 DC

* Under construction.

Notes: MW = megawatt; AC = alternating current; DC =direct current.

Distribution

Denmark has 160 000 km of distribution lines, which are owned and operated by 38 distribution system operators (DSOs). Some are owned by a holding company while others are owned by consumers or municipalities.

DSOs have been unbundled since 2004. There are around 3.3 million distribution customers. DSOs in Denmark are relatively small, with on average just over 54 000 customers, so they fall below the EU unbundling requirements of the large DSOs. There are 57 electricity suppliers in Denmark.

The DSOs' tariff methodology and the connection fee methodology are approved by the Danish Utility Regulator (DUR) based on an industry-wide tariff model under the rules of the Danish Electricity Supply Act and the Electricity Market Regulation.

Denmark upgraded its revenue cap model in 2018.[5] DUR moved to a new, enhanced regulatory model developed by the DEA with input from the DSOs, the DUR and consumers. The new model includes an explicit incentive for efficiency improvements, a cap on returns from investments, returns for future investments with a market-based weighted average cost of capital, and a reduction in the cap should the "quality of supply" decline (for example, an increase in the number of outages). The model allows for more variation in how tariffs are set, in particular opening up the possibility to apply time-of-use tariffs for all customers.

The new model also includes an additional "availability" tariff. This is aimed specifically at consumers who install distributed generation, notably solar PV. The purpose is to ensure that consumers pay for their share of the grid costs, even if they do not utilise the grid 100% of the time. For large producers, the tariff is calculated on a case-by-case basis, but for small consumers (households) it is fixed and applied equally to everyone.

The 2021 policy agreement "A future-proof electricity infrastructure to support the green transition and electrification" sets out plans for a new regulatory framework for DSOs to stimulate timely investments and incentivise flexibility.

An average electricity consumer in Denmark experiences about 20 minutes System Average Interruption Duration Index (SAIDI) per year. These are all related to grid failures, as there have not been any interruptions due to power system failures historically. Network losses are at about 2% in transmission and 4% in distribution.

[5] Revenues were fixed every year on the basis of the "regulatory price" of electricity distribution multiplied by the expected volume of electricity transported in kilowatt-hour terms.

Electricity market and prices

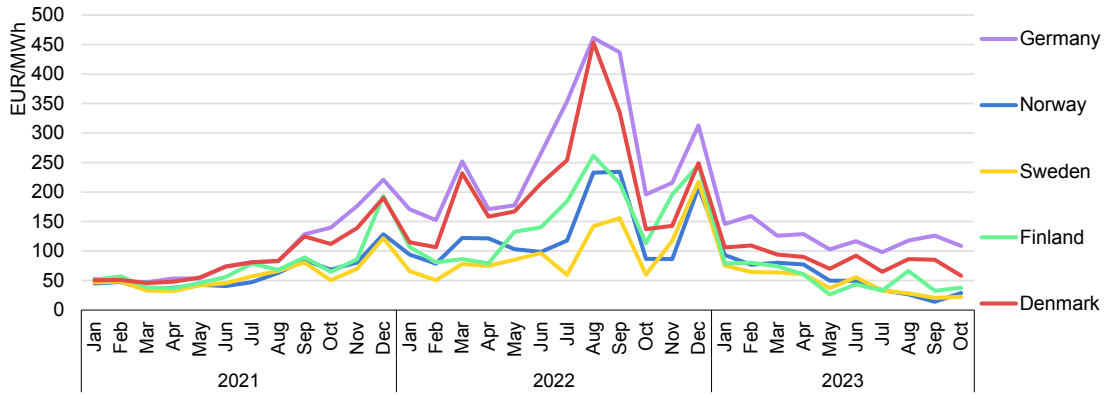
Wholesale market

The Danish power system is part of both the Nordic system and the Continental European market. The Danish bidding zone DK1 is part of the Continental European synchronous area, while the DK2 bidding zone is part of the Nordic synchronous area. Denmark's price zones are impacted by hydropower availability in the Nordic system and the price of electricity in continental Europe.

The Nordic market has multiple price zones: Denmark (2), Norway (5) and Sweden (4). Price variations can be large, as there is congestion and not enough transmission capacity to transport electricity from low-priced zones towards those with higher prices. If it were possible to transmit available supply, prices would average out across the entire region. In Denmark there is structural congestion at the Great Belt. Denmark is, therefore, divided into two price areas, DK1 and DK2.

Denmark participates in the Nord Pool wholesale market, along with the other Nordic countries and the three Baltic states: Estonia, Latvia and Lithuania. Nord Pool is owned by Euronext (66%) and TSO Holding (34%), which organises the shareholdings of the Nordic and Baltic TSOs. Nord Pool has two physical markets: Elspot, the day-ahead market; and Elbas, the intraday balancing market. Denmark, along with the rest of the Nordic region, is part of the single day-ahead coupling and the single intraday coupling markets and is coupled to large parts of Europe. This means that wholesale prices in Nord Pool and the majority of Europe should accurately reflect the expected direction of power flows (Figure 9.9).

Figure 9.9 Wholesale electricity prices in Denmark and selected countries, January 2021-October 2023



Source: IEA (2023), Real-time Electricity Demand, Generation and Wholesale Prices.

Retail market

In 2020, 44 suppliers sold 308 different retail products in total, of which 268 in East Denmark and 277 in West Denmark. The common retail product was a three-month fixed-price contract, which is held by 48% of households. Fixed-price contracts with longer periods are 9% of the market. The remaining 43% of retail contracts were flexible, covering contracts from hourly to bi-monthly prices.

Around 35% of total electricity volume sold to consumers is through "*klimaprodukt*" contracts, using guarantees of origin that confirm that an equivalent quantity of energy has been produced from renewables. For some products, additional climate measures that may contribute to reducing GHG emissions are also included. Distribution may look significantly different in 2022, which was characterised by high electricity prices.

For an average household customer, the electricity bill in 2021 could be broken down as follows: energy costs (17%); network costs (18%); and taxes (65%). The political Winter Help Agreement (September 2022) allowed for the temporary easing of the electricity tax in the first half of 2023.

With the overall increase of electricity prices in Europe, in Q2 2022, a larger share of the bill was from energy costs (43%) and a smaller share from taxes (25%), as the PSO was annulled and the tax level was reduced. Value-added tax was still 20%, the TSO payment 3%, DSO payment 7% and subscription with the supplier 2%.

Until 2022, the PSO tariff was used to finance the costs of the TSO, in line with the Danish Electricity Supply Act. The bulk of the PSO revenue was used to finance renewable subsidies, which are now financed through the national budget.

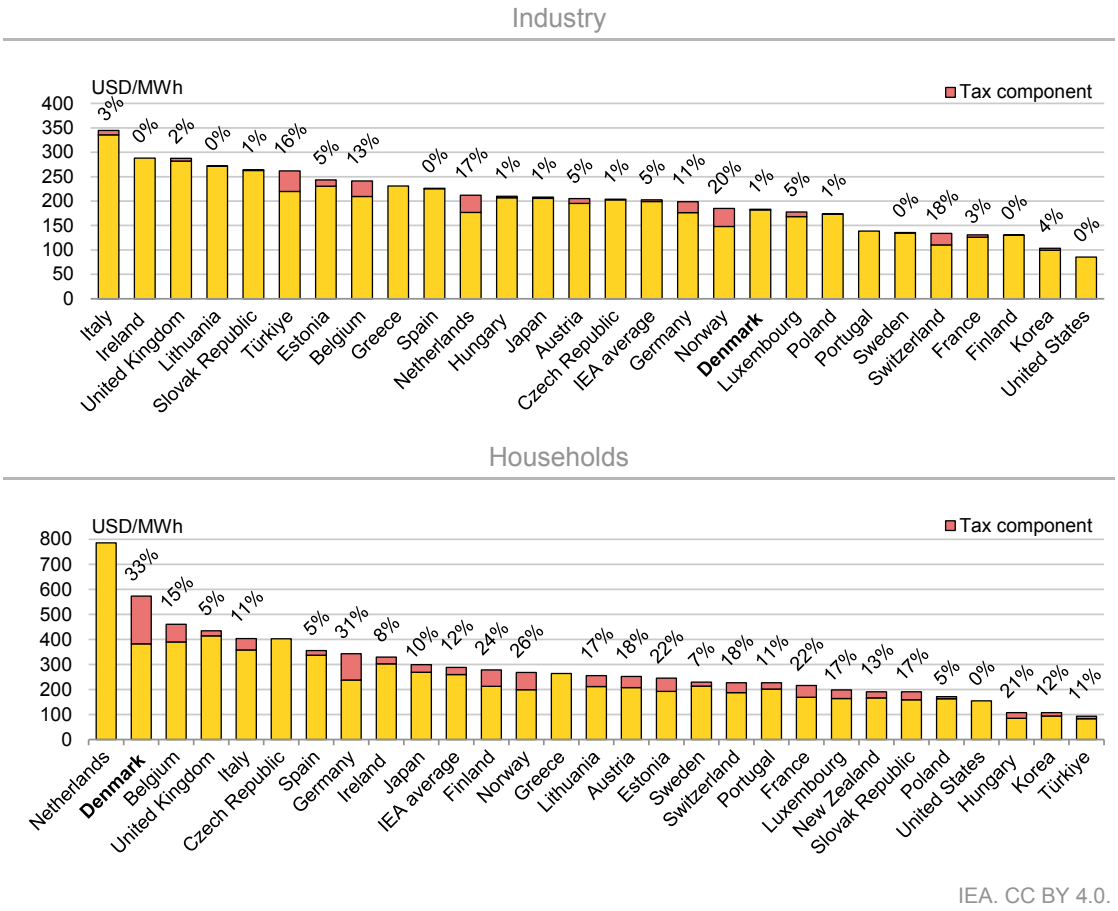
The switching rate for household and non-household customers with an annual consumption of up to 100 000 kWh has remained constant at 7.4% since 2014. The share may be significantly different in 2022, which was characterised by high electricity prices.

Retail prices and taxes

Denmark's industry average price in Q4 2022 was 183.3 USD per megawatt hour (MWh), with a 1% tax rate, below the IEA average of 202.7 USD/MWh, with an average tax rate of 5% (Figure 9.10).

The average Danish household electricity price in Q4 2022 was 572.9 USD/MWh, with a 33% tax rate. This was the second-highest electricity price among IEA member countries. The IEA average household price in the same quarter was 287.9 USD/MWh, with an average tax rate of 12%.

Figure 9.10 Electricity prices for industry and households in IEA member countries, Q4 2022



Note: Industry prices are not available for Australia, Canada, Mexico or New Zealand. Household prices are not available for Australia, Canada or Mexico.

Source: IEA (2023), Energy Prices.

Electricity security

The Ministry for Climate, Energy and Utilities has oversight over electricity policy, including security of supply. As a part of the Ministry, the Danish Energy Agency is responsible for the data and technical analysis on energy production, supply and consumption, including electricity.

The DUR is an independent institution responsible for regulating the Danish markets for electricity, natural gas and district heating. In the electricity market, the regulation focuses on the network companies, which are also suppliers. The DUR sets the allowed price for electricity companies with an obligation to supply.

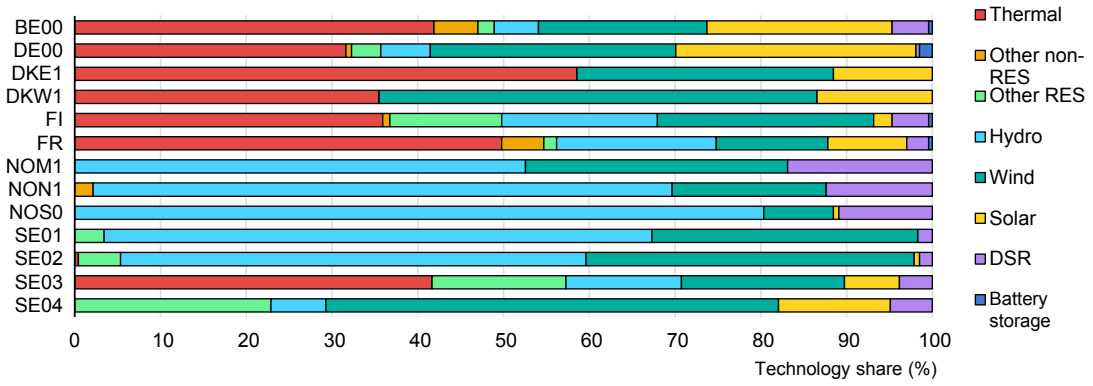
The Minister for Climate, Energy and Utilities is responsible for setting the level of electricity supply security (Electricity Supply Act, Article 27). The TSO (Energinet) has the operational responsibility for security of supply and also produces an annual report on electricity supply security. Energienet recommends the level of security of supply to the Ministry. As with other EU countries, Denmark's electricity emergency preparedness and emergency response procedures are also governed by EU Regulation (2019/941).

In 2020, Energinet recommended an overall planning objective for 2030 of 35 outage minutes in total with two elements. Energinet's recommendation on generation adequacy and the electricity transmission grid totals seven outage minutes in 2030, which matches the planning objective set by the Danish Minister for Climate, Energy and Utilities in January 2020. The grid enterprises project 28 outage minutes in 2030 at the electricity distribution grid level, which matches the grid enterprises' projection from 2019.

Power system adequacy

Denmark enjoys high levels of adequacy with an installed capacity much above its peak demand. The latest ENTSO-E 2022-23 winter outlook stresses that Denmark's thermal net generation capacity is largely above peak demand; however, there was a low level in DKE1 in winter 2022/23 (Figure 9.11). DKE1 relied mostly on imports during the winter period.

Figure 9.11 Denmark's generation capacity mix and adequacy per region



Notes: RES = renewable energy source; DSR = demand-side response.
Source: IEA analysis based on ENTSO-E (2022), Winter Outlook 2022-2023.

Power system integration

Within the IEA's six phases of system integration, Denmark is now in phase 5 and must deal with the various impacts resulting from it, with longer periods of variable renewable energy surplus production (from days to weeks) or energy deficits. Another issue is to ensure the integration of offshore wind in terms of contingency to loss of connection. The Danish electricity system will see a major transformation in the coming decade. In 2021, the share of variable renewables (wind and solar PV) reached 53%, supported by a dispatchable share of 29% of bioenergy and waste. In 2030, Denmark expects to have a share of renewables above 100%.

With the adoption of the Climate Agreement on Green Power and Heat (2022), for 2030, Denmark decided to quadruple electricity production from solar and onshore wind, adding 50 TWh and announced a tender of at least 4 GW of offshore wind. Political agreements for offshore wind farms are expected to lead to the deployment of 20 GW, including the two energy islands. This corresponds to the power consumption of more than 23 million European households.

Several system integration approaches are being deployed, including energy islands (see Box 8.1) and PtX, which are going to be regional in scope and cross-sectoral, requiring a new approach to market design and system integration in many respects.

Denmark has not had a strong demand response programme in the past and is advancing battery storage pilots. Progress is underway for developing district heat as thermal storage and smart meters/grids and aggregators. The roll-out of smart meters and the possibility of flex-billing was completed at the end of 2020 so electricity consumption can be settled on an hourly basis. New products offered by aggregator companies can be expected on the market in the future. A new countertrade model is being implemented allowing Energinet to buy countertrading services on the intraday market (as opposed to before, when Energinet was compelled to downregulate Danish producers). This new arrangement will result in more competitive bids from a larger market, primarily from Norway or Sweden and even the consumer side, which is unable to participate in countertrading today.

The Agreement on the Development and Promotion of Hydrogen and Green Fuels 2022 (the PtX Agreement) supports the framework for electricity from wind farms to be used by PtX facilities and potentially contribute to decarbonising aviation and heavy transport. PtX should contribute to reducing the need for network expansion by ensuring that renewable energy and consumption are placed in the same geographical area for faster integration. In 2022, Denmark introduced geographically differentiated tariffs and the allowance of direct lines between generators and producers.

Today's Danish power system integration approach was based on boosting incremental flexibility, based on the "Energiaftalen" Agreement (June 2018) and Denmark's implementation of the EU Clean Energy Package and Electricity Directive 2019/944.

The so-called Market Model 3.0 set out a vision with five priorities:

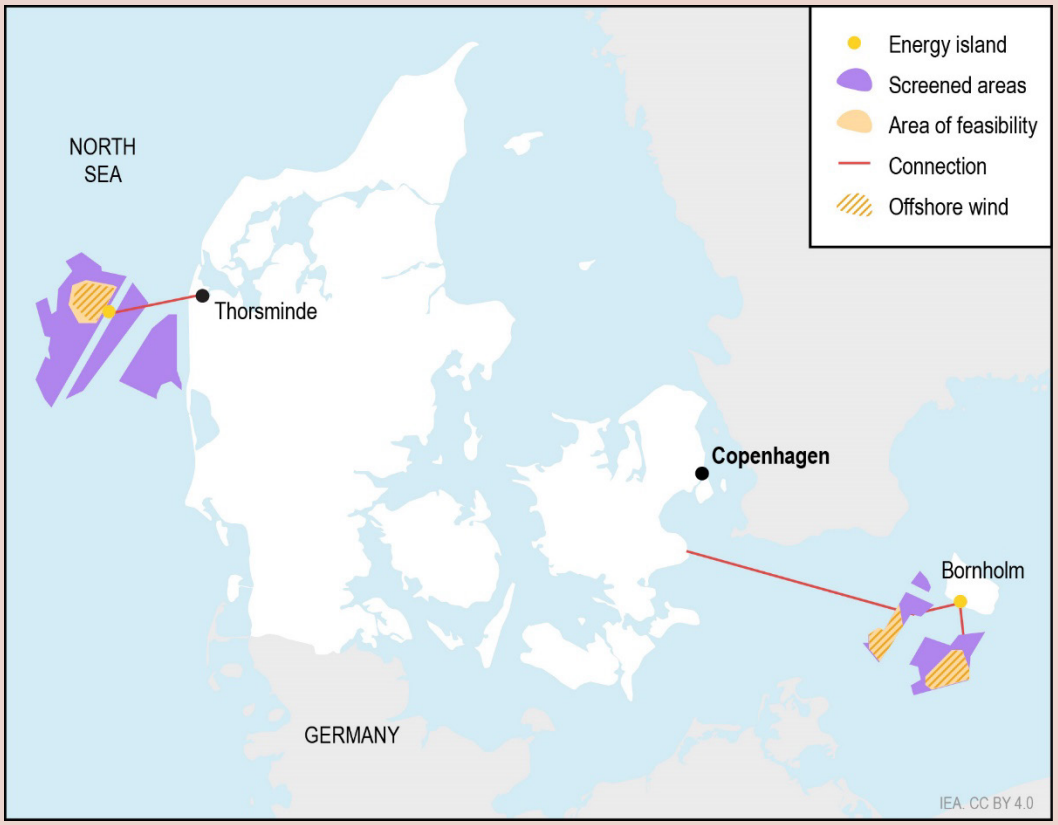
- 1. All actors must contribute to a flexible electricity market.
- 2. Flexibility must ensure a robust energy system in balance.
- 3. The flexible electricity market must ensure a cost-effective expansion of the grid.
- 4. The regulation of monopoly companies must promote a flexible electricity market.
- 5. The electricity market model must be at the forefront of the development with increased transparency and a strengthening of energy communities.

Box 9.1 Energy islands

Energy islands are renewable power plants gathering electricity from the offshore wind farms and serving as energy hubs to distribute it to the electricity grid in Denmark and other countries (Belgium, Germany, the Netherlands and Sweden). Denmark supplies electricity directly to the national electricity grid from isolated offshore wind farms (radial connections).

In order to locate the wind turbines further from the coast and distribute power more efficiently, Denmark is building two energy islands, one in the Baltic Sea and the other in the North Sea. While the energy island in the Baltic Sea is established on land (Bornholm), the one in the North Sea is to be an artificial island, located about 80 km off the coast of Thorsminde in Jutland. During the first phase, 3-4 gigawatts (GW) of electricity will be produced from the North Sea and 3 GW from Bornholm. The capacity will be expanded to generate 10 GW.

Figure 9.12 Energy islands in Denmark



Source: Danish Energy Agency (2023), Climate Status Outlook 2023.

Electricity emergency response

The Minister for Climate, Energy and Utilities is responsible for setting the level of electricity supply security (as specified in the Electricity Supply Act). The TSO (Energinet) has the operational responsibility for security of supply. Energinet produces an annual report on electricity supply security.

The legal framework for electricity preparedness is set out in Legislation 2646 on preparedness for the electricity sector and Legislation 2647 on preparedness for the electricity and natural gas sectors.

Every year, companies of regional and national importance must deliver updated contingency plans and answer the DEA's risk and vulnerability analysis request by 1 October at the latest. The risk and vulnerability analysis for 2023 contained 37 scenarios. Every year, based on a company's categorisation and classification, the DEA approves or denies the material the company sent. If denied, the companies have to revise the material. Every third year the risk and vulnerability report will be on both physical scenarios and IT/OT scenarios. In the years between, the risk and vulnerability scenarios only focus on

IT/OT vulnerabilities. The companies' risk and vulnerability reports are further distributed to Energinet, the TSO, which produces a sector report on the most critical vulnerabilities.

Denmark has a relatively low reserve capacity in thermal baseload units and emergency response is based on imports and/or load shedding by the TSO.

Interruptible contracts are not common among existing consumers but are being developed for new consumers, such as PtX. Their methodology must be approved by the DUR.

About 50% of Danish power production is wind and solar, and does not thus depend on fuel. The large power plants typically have at least two fuel options (biomass, coal, oil or natural gas). Small-scale co-generation plants (about 1 500 MW installed capacity on natural gas, waste, biomass or biogas) usually only have one fuel option, thus no fuel switching is possible.

Procedures are in place for rolling brownouts in case of supply inadequacy. The TSO decides how many megawatts are to be shed. Distribution companies are responsible for the actual load shedding. Load shedding happens in a number of steps, each comprising a certain number of megawatts corresponding to steps of 10% of consumption. There is no prioritisation of consumers. Due to the increased risk of brownouts in the coming winters, a new workstream in the national crisis management organisation (NOST) was created to ensure that all critical sectors are prepared for a possible brownout.

Assessment

Denmark is part of the Nordic power market with Finland, Norway, Sweden and the Baltics (Nord Pool), and the wider European power market.

Denmark's annual electricity production was 34 TWh in 2022, a decrease from a peak of 45.6 TWh in 2006. The electricity generation mix has undergone a major transformation over the past decade, with the share of coal decreasing from 43% to 13% and the share of wind increasing from 18% to 54%. The share of natural gas has also decreased, from 24% to 3%, while bioenergy has increased from 11% to 29%.

In 2021, total installed electricity generation capacity in Denmark, excluding distributed generation, was 16.6 GW. Combustible fuels accounted for 51% of total installed capacity, wind for 40% and solar for 8%. Wind capacity has doubled since 2005 and solar has almost tripled since 2012. Fossil fuel capacity has been declining, from close to 10 GW in 2005 to 8.4 GW in 2013 and 7.9 GW in 2021.

Electricity demand in Denmark was 32 TWh in 2022. Overall, it has remained stable around 30-35 TWh, with lower levels during the 2010s. In 2022, the industry sector accounted for 36% of the total electricity demand, followed by residential buildings (32%), services sector buildings (29%) and transport (2.0%). However, there has been an important uptake of electricity for the transport sector, with demand doubling over the 2005-22 period, but from a low level.

Future electricity demand trends are contingent on the build-out of electrolyser capacity, the pace of electrification and the number of data centres. Denmark is attracting a growing number of the world's tech companies and is transforming into a power hub for

international data centres. According to the IEA's *Tracking Clean Energy Progress 2022*, data centre energy demand is projected to triple by 2025 to account for around 7% of the country's total electricity use.

Wholesale electricity markets

Over the past 15 years, Denmark has mainly been a net importer of electricity, after having been a net exporter in 2006, 2007 and 2010. Net imports of electricity increased from 2013 to 2015, as coal-fired power generation was phased out. Imports have stabilised in recent years. In 2022, Denmark exported 7.54 TWh of electricity, mainly to Germany and the Netherlands, and imported 10.31 TWh of electricity from Norway and Sweden. While Denmark has been a net importer for the last decade, it is expected to turn into a net exporter in the coming years, as a result of increasing interconnection capacity and expected large deployment of wind and solar.

Several new interconnectors have been commissioned in the last years: the COBRA interconnector linking Denmark to the Netherlands; the new hybrid interconnector via Kriegers Flak to Germany; and the Viking Link Cable to Great Britain, currently under construction but expected to enter into operation in 2023.

The DUR is an independent institution responsible for regulating the Danish markets for electricity, natural gas and district heating. In the electricity market, the regulation focuses on the network companies, which are also suppliers. The DUR sets the allowed price for electricity companies with an obligation to supply. In 2023, the DUR has shifted from a strict *ex post* cost-plus to an *ex ante* revenue model for network regulation in Denmark.

System- and grid-friendly deployment of renewable capacity across Denmark is encouraged. New grid tariffs on producers of renewable energy were recently introduced. Denmark is divided into areas of production and areas of consumption. New renewable energy projects developed in production areas have seen cost increases.

The Danish transmission system is divided into two distinct grids: DK.1, or the western grid, which covers Jutland and Funen; and DK.2, or the eastern grid, covering the islands of Zealand and Bornholm. While Energinet is responsible for both systems, they are operationally distinct. DK.1 is synchronised with Germany and the rest of continental Europe while DK.2 is synchronised with Sweden and the rest of the Nordic region. The only direct interconnection between DK.1 and DK.2 is the Great Belt Power Link, a 400 kV DC line with a capacity of 600 MW. There is considerable congestion between the DK1 and its neighbouring continental European power system.

Retail markets

In 2020, 44 suppliers sold a total of 308 different retail products in Denmark, of which 268 in DK2 and 277 in DK1. The common retail product was a three-month fixed-price contract, which was chosen by 48% of households.

With the end of the public service obligation and the rise in wholesale energy prices, the consumer bill has changed. In Q2 2022, taxes made up the lion's share (45%) of households' energy bills, followed by energy costs (43%), the TSO payment (3%) and the DSO payment (7%), with a standing subscription fee of 2%. By comparison, the electricity bill in 2021 had energy costs of 24%, with network costs accounting for 17% and taxes for

65%. The Winter Help Agreement of September 2022 allowed for a temporary easing of the electricity tax in the first half of 2023.

Denmark's industry average price in Q4 2022 was 183.3 USD/MWh, with a 1% tax rate, below the IEA average of 202.7 USD/MWh, with an average tax rate of 5%. The average household electricity price in Denmark in 4Q 2022 was 572.9 USD/MWh, with a 33% tax rate. This was the second-highest electricity price among IEA member countries. The IEA average household price in the same quarter was 287.9 USD/MWh, with an average tax rate of 12%.

The roll-out of smart meters and smart billing were completed in 2020. However, switching rates of households and SMEs have not increased since the IEA's last review and remain at 7.4% in 2021. Thanks to smart apps with data provided by Energinet and the introduction of grid cost-reflective peak hourly pricing, more public attention is paid to demand response. Denmark should ensure that competition between electricity suppliers continues. Updating the price comparison tool (elpris.dk) was a step in the right direction in this respect. The next step should be the use of products offered by aggregators to handle the flexibility of heat pumps and EV charging.

Energinet's DataHub collects Danish electricity consumption data, building on the 100% smart meter roll-out. The DataHub is owned and operated by Energinet. In addition to storing vast volumes of information about customers, consumption and prices, DataHub handles all data communication between market participants in the electricity market.

Recommendations

The government of Denmark should:

- Prepare an energy system plan for 2045 to support the development of variable renewable electricity generation; the phase-out of thermal generation; and the development of demand from district heating, individual heat pumps, electric vehicles, data centres, and Power-to-X and its flexibility, to proactively ensure that fuel, generation, and network adequacy and reliability are maintained in the medium and long terms.
- Facilitate the role of aggregators for electric vehicles and heat pumps, taking advantage of the DataHub, smart metering and increasing flexibility of consumers to reduce demand when there is scarcity.
- Ensure the development of transmission and distribution grid infrastructure to accommodate future demand and generation growth by improving the regulatory frameworks for transmission and distribution system operators.
- Continue to use direct lines to co-locate production and demand to facilitate the green transition.

10. Energy sector integration

Key data (2021)

Share of electricity in TFEC: 21% (IEA average: 25%)

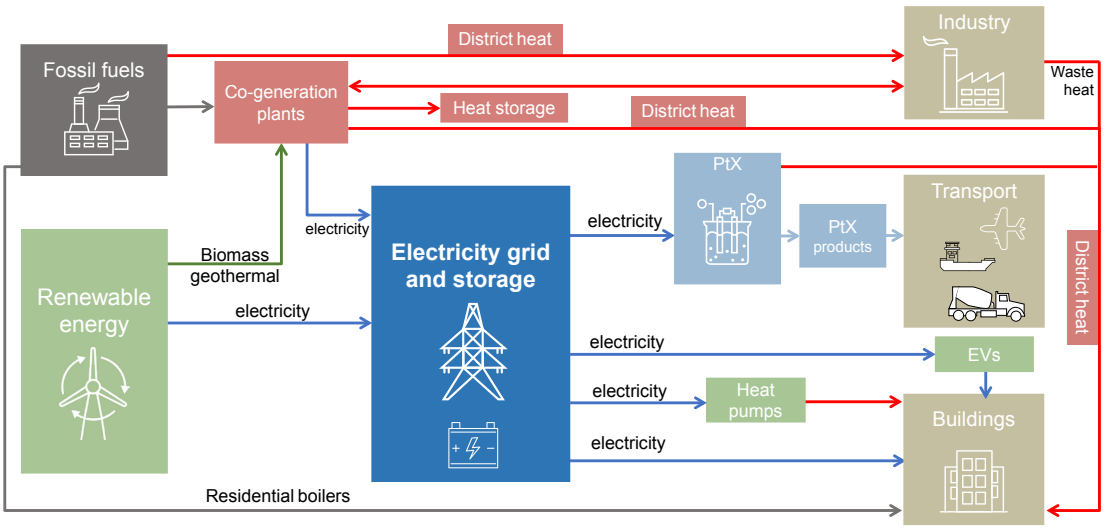
Share of direct use of renewables in TFEC: 40% (IEA average: 14%)

Share of renewables in power generation (2022): 81% (wind 54%, bioenergy 20.7%, solar 6.3%)

Targets and strategies

Denmark is actively pursuing an energy system approach. Building on its leadership, the government has made sector coupling a key plank of its decarbonisation policy approach. The government released a dedicated PtX Strategy in 2021 and created a PtX Taskforce in 2022. Denmark's strategy to fully decarbonise its economy, aiming at net zero emissions by 2045, relies on extensive electrification. Figure 10.1 shows the importance that the integration among the electricity, heating, fuel and PtX sectors plays today in the Danish energy system.

Figure 10.1 Illustration of the integration of electricity, heat and transport in the Danish energy system



IEA. CC BY 4.0.

Note: PtX = Power-to-X.

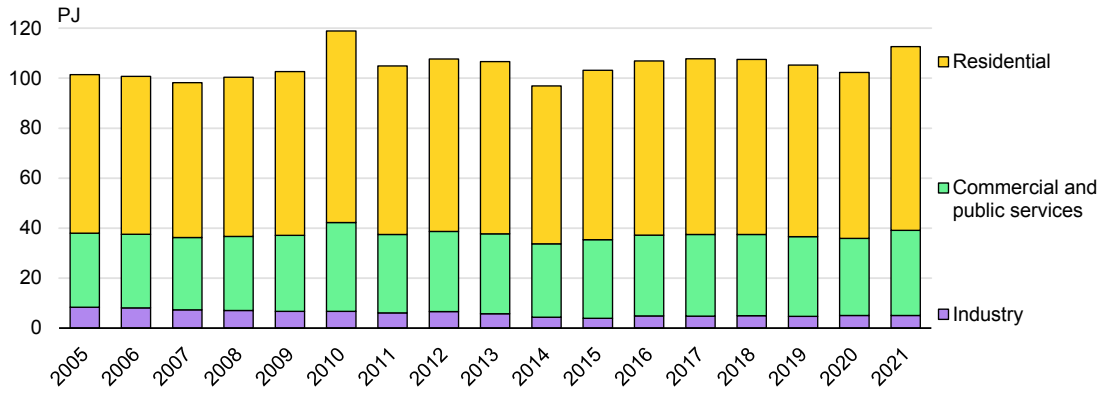
Electricity demand from all sectors is expected to grow. Denmark's energy policies are focused on transitioning the power generation sector so that the integration of each sector benefits the whole system. For instance, Denmark's extensive use of co-generation plants allows households and industries to receive district heat. The decarbonisation of the heating sector implies the increasing use of clean district heat, powered with biomass and geothermal, and alternative ways of heating houses, such as heat pumps. Heat pumps are to be powered by renewable electricity, mainly wind power in Denmark. Excess wind energy will be used for PtX plants, to produce, for instance, hydrogen, which will contribute to the decarbonisation of hard-to-abate sectors.

Integration of heat and electricity systems

District heating and co-generation

Denmark has the highest share of district heat in end-use sectors (39%) in the IEA. In 2021, total district heat consumption was 113 PJ, 19% of TFEC (Figure 10.2). District heating is the first source of space heating in the residential sector, which covers 65% of TFEC: nearly two-thirds of Danish consumers receive district heat, or 1.7 million houses and buildings. The commercial sector and industry cover the remaining share of district heat, accounting for 30% and 5%, respectively. Total district heat consumption had an upward fluctuation in 2010 due to exceptionally cold weather and a downward fluctuation in 2014. From 2015 to 2018, the trend was positive; total district heat peaked in 2018 and started decreasing afterwards.

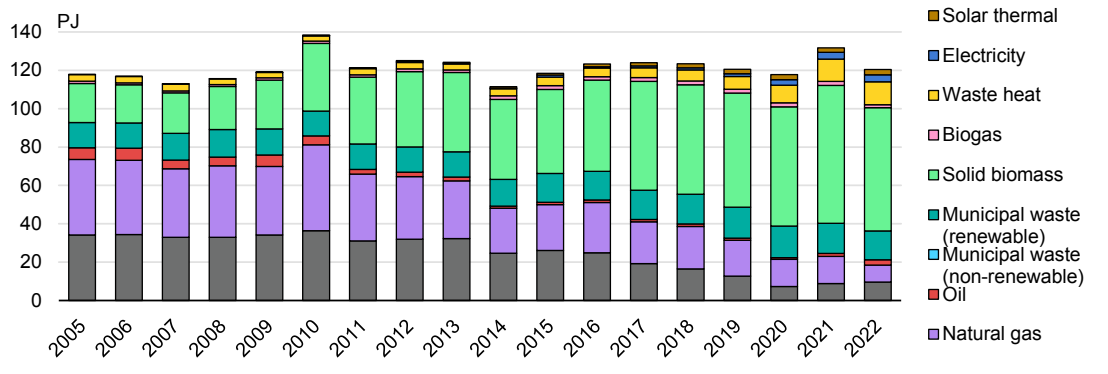
Figure 10.2 District heat consumption by sector in Denmark, 2005-2021



Source: IEA (2023), World Energy Balances.

Since 2005, annual district heat production has fluctuated over time at around 120 PJ, with a peak in 2014 of 140 PJ (Figure 10.3). The fuel mix of Denmark's heat generation has evolved over the years. There were high shares of natural gas and coal in 2011, 50% combined, which decreased to 14% in 2022 to be replaced by an increasing share of biomass. Solid biomass now represents 50% of district heat generation, from 26% in 2011. Heating from waste heat has increased considerably in recent years and accounted for 9.2% of total heat production in 2021. Overall, district heat relied on renewable sources for 65% of the total.

Figure 10.3 District heat by source in Denmark, 2005-2022

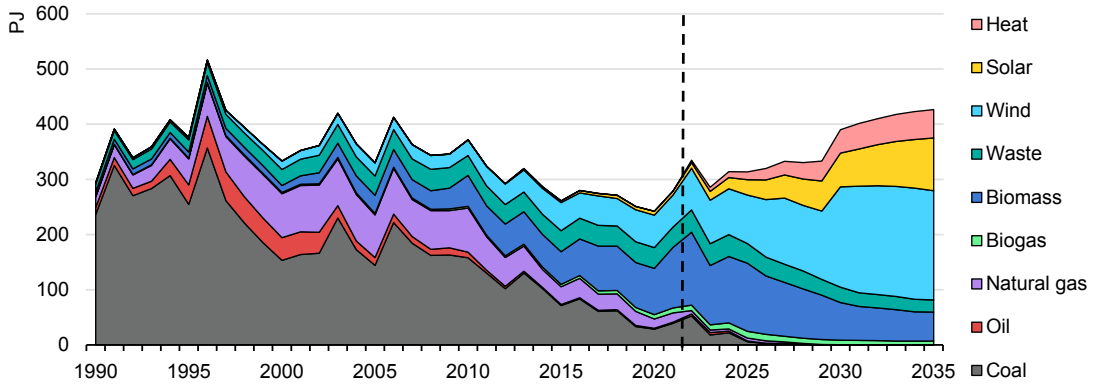


Source: IEA (2023), World Energy Balances.

District heat is highly developed because of the extensive diffusion of co-generation facilities in Denmark. In fact, around 66% of district heat comes from co-generation (the remaining share comes from heat-only boilers). Denmark has around 670 decentralised and decentralised co-generation plants; approximately 500 companies operate on the district heat value chain and 385 companies deal with distribution to consumers. Distribution companies are often owned by municipalities or consumer-led co-operatives and produce the heating they distribute. A share of distribution companies is privately owned and a last share of companies produces and sells to the distribution companies. In this last case, district heat is produced from industrial waste heat, waste-to-energy plants, and large public or private co-generation plants.

Denmark relies on district heat especially for the decarbonisation of the residential sector, as it aims to phase out the use of gas for space heating by 2035, under the Agreement on Green Power and Heat (25 June 2022). In April 2022, the government put forward plans to convert around 50% of Danish households (that are currently heated by natural gas) to district heating by 2028. The Agreement also prohibits new district heat projects that use fossil fuels.

Figure 10.4 Energy consumption in electricity and district heating in Denmark, historical and forecast, 1990-2035



Source: IEA analysis based on DEA (2023), Climate Status Outlook.

The production of district heat from renewable sources is at the core of Denmark's green policy. The government has introduced several policies to promote district heat while phasing out gas and oil boilers for heating.

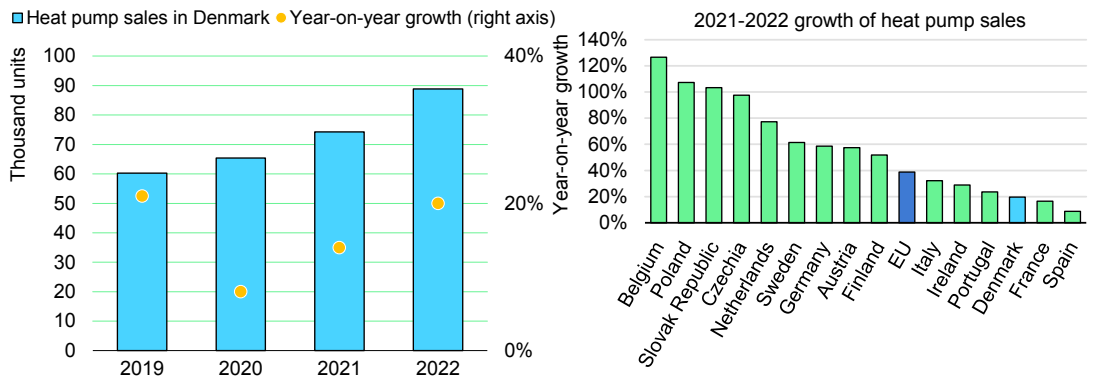
First, in 2019, it terminated the support scheme for decentralised co-generation plants fuelled with natural gas. Second, it removed electricity and heat co-generation requirements for district heat to promote the electrification of the heating sector by giving heating companies more freedom with regards to which technology to adopt, such as geothermal. In fact, in 2020, geothermal plant operators and district heat companies were given the possibility to adhere to a different price regulation scheme to facilitate their expansion in Denmark. In addition, from 2021, the electric heating tax was lowered to the EU minimum. In January 2022, the DEA set a measure to promote renewable sources of district heat involving the introduction of a price cap on the total costs of waste heat to limit the production and use of waste heat. In 2020, fuel support schemes for natural gas were also removed.

Heat pumps

Heat pumps are being considered in Denmark for heating and cooling production in individual households and private companies. In particular, heat pumps represent a sustainable alternative for houses for which district heat is not a viable option.

Heat pump sales grew by about 14% from 2020 to 2021 (Figure 10.5), and around 80 000 heat pumps are installed and currently operative in Denmark. Denmark ranks lower than France and Italy, among others. The recent growth is due the low investment costs for residential heat pumps (including installation) for lower cost air-to-air heat pumps compared to gas boilers. Hydronic (air-to-water) heat pumps typically entail higher investment costs than air-to-air heat pumps, while ground-source heat pumps are the most expensive, owing partly to the installation of the underground heat exchanger, which can represent more than half of the total system costs (Figure 10.6).

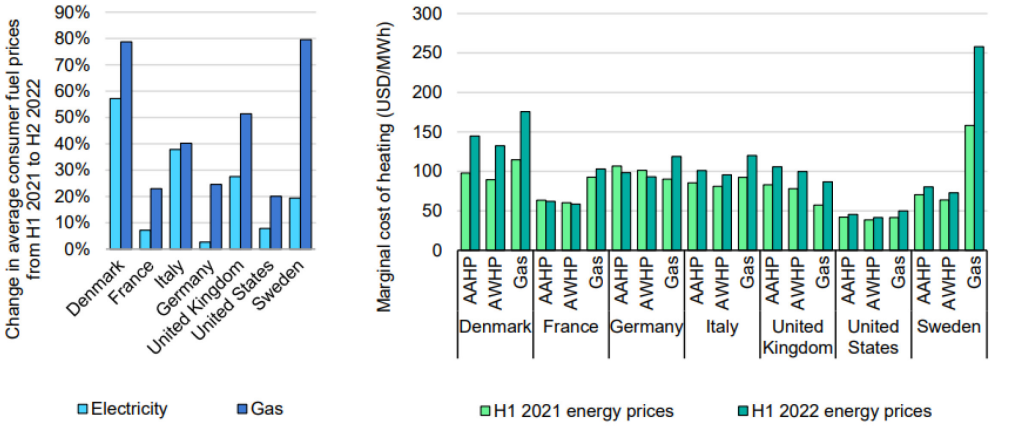
Figure 10.5 Heat pump sales and growth in Denmark and selected EU countries, 2019-2021



Heat pump manufacturers are working in co-operation with grid operators in leading heat pump markets to test how to harness demand flexibility from heat pumps for grid stability. For instance, German manufacturer Viessmann acts as aggregator in a pilot project to test the flexibility potential of the heat pumps of customers who have agreed to join the scheme

and offers the resulting energy volume to the grid operators via the Equigy crowd balancing platform – a data exchange to enable aggregators of small loads to participate in electricity balancing markets – to reduce load at peak periods.

Figure 10.6 Levelised cost of heating for air-to-water heat pumps and gas boilers for selected countries, and fuel-price sensitivity, from H1 2021 to H2 2022



Notes: CAPEX = capital expenditures; OPEX = operational expenditures; AAHP= air-to-air heat pump; AWHP = air-to-water heat pump. H1 = first half.

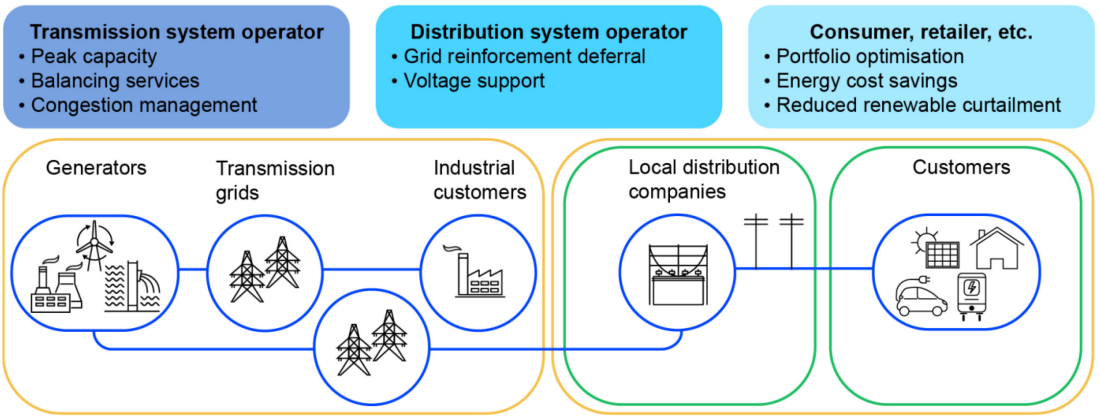
Source: IEA (2022), Renewables 2022.

Between 2018 and 2020, the government put in place a subsidy scheme for households and companies to promote the conversion to district heat and domestic heat pumps. Among the measures for households, there is a support measure for households' expenditure to disconnect from the gas network (the disconnection scheme, Afkoblingsordningen). The scrapping scheme (Skrotningsordningen) entails a subscription system to a heat pump for users that cannot bear the investment of a heat pump. The provider takes care of the installation, operation and maintenance, while holding ownership of the heat pump. The building scheme supports individual investments in heat pumps and the district heating scheme (Fjernvarmepuljen) supports the investment of the creation of new district heat areas, to lower consumers' costs. As for the subsidy measures for companies, the enterprise scheme (Erhvervspuljen) provides support to projects aimed at reducing energy consumption or CO_2 emissions. The district heating production scheme (Etableringsstøtten) promotes the reduction of fossil fuels in district heat plants through support to investments in large heat pumps and a solar heating system.

Integration of transport and electricity system

EVs can be an opportunity to optimise the electricity system, if smartly managed. EVs could, for example, charge their batteries outside peak hours, or act as batteries connected to the grid, increasing flexibility. Such an integrated system requires collaboration between the TSO and DSOs, consumers and retailers.

Figure 10.7 Actors involved in an integrated energy system



Source: IEA (2022), Global Electric Vehicle Outlook 2022.

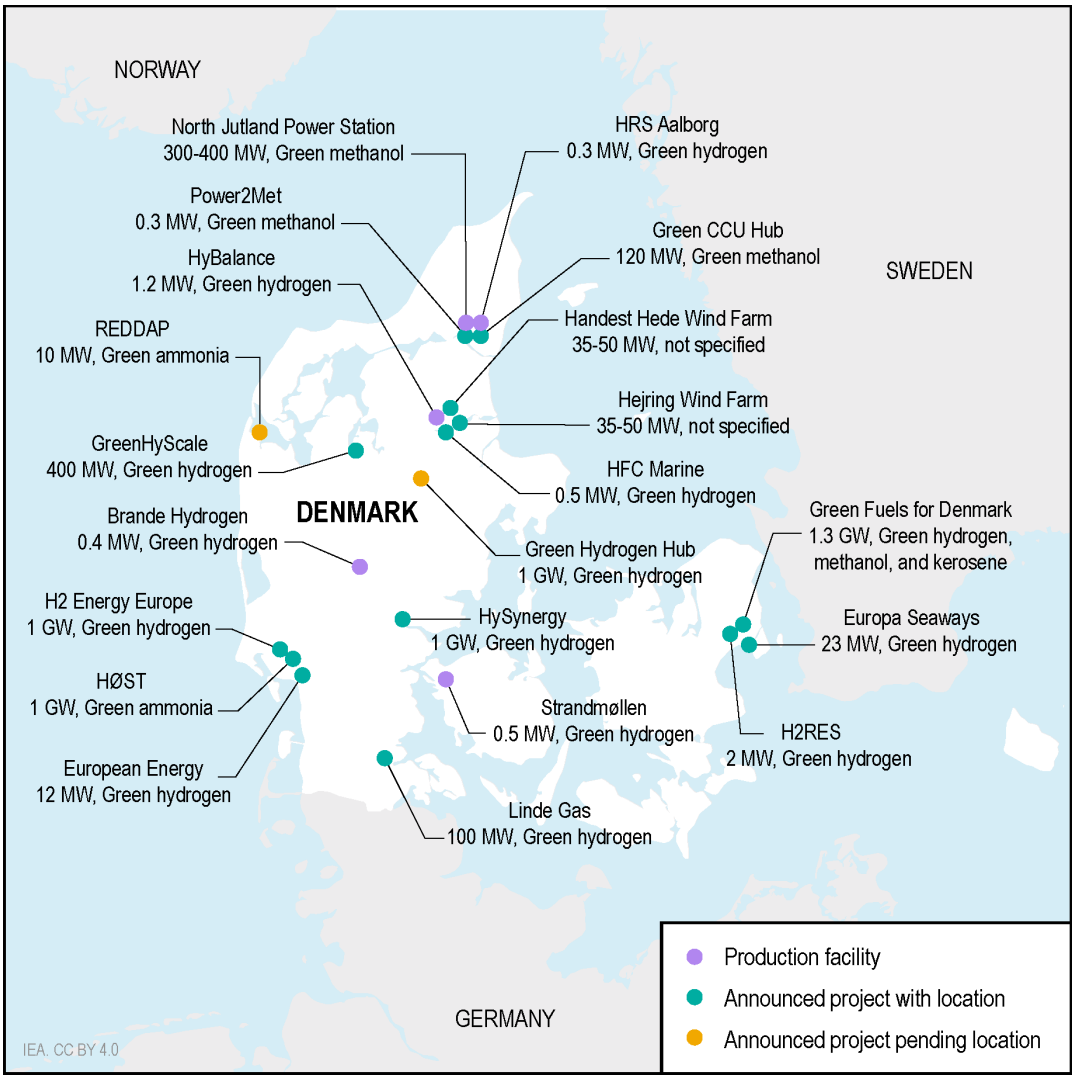
As described in Chapter 6, Denmark's share of EVs in the car stock was 5.2% in 2021, lower than Norway (25%) and Sweden (6%) but higher than Finland (3.6%) and the Netherlands (4.4%). Denmark's transport sector has a low level of electrification. Transport only accounted for 2% of the electricity in TFEC in 2021 and the demand for energy sources other than oil in the transport sector only covers 8%, of which 1% from electricity and the remaining share from biofuels.

Power-to-X integration

In 2021, the Danish government presented the Strategy for Power-to-X to help guide and promote the development of PtX. PtX is seen as complementary to the electrification strategy, as it contributes to the decarbonisation of harder to electrify sectors, such as aviation and maritime transport and heavy road transport.

The PtX Strategy promotes four goals. First, PtX must help achieve Denmark's climate objectives, both for 2030 and for 2050. Second, a regulatory framework must be created for PtX. Third, the Danish energy system must be integrated with PtX for better co-ordination in the production of electricity from variable renewable energy sources and electrolysis plants. The production of green gases and fuels through PtX is highly energy-intensive and generates surplus heat. The flexibility of the electrolysis plants can benefit the power system. Last but not least, Denmark wants to become an exporter of PtX products and technologies, as capacity increases over the years beyond domestic needs.

Figure 10.8 Denmark's Power-to-X Strategy and key projects



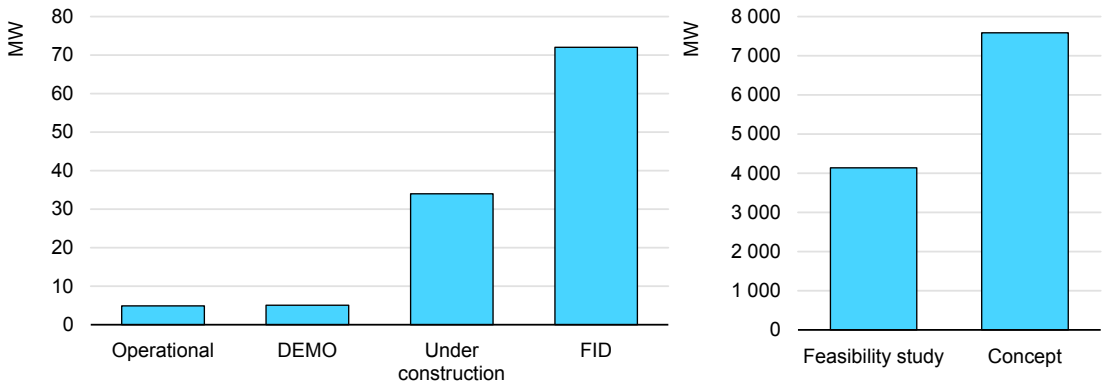
Source: Denmark, Ministry of Climate, Energy and Utilities (2021), The government's Strategy for Power-to-X.

Denmark's goal is to build 4-6 GW of electrolysis capacity by 2030; data on current production are currently not systematically collected. PtX will create an integrated energy system along with the electricity, heating and gas systems. The interaction with the electricity system will be at the core of the PtX Strategy. Electrolysis plants will consume the oversupply of electricity produced with wind or other renewable energy sources and will be shut down when wind is not blowing. The surplus heat generated with PtX plants would also be injected into the district heating grid.

PtX projects currently in place in Denmark, measured by their capacity, only represent a negligible share (4%) (Figure 10.9) compared to the projects that are under construction (29%) and in final investment decision phase (62%). The remaining share of the projects are in a demonstration phase (4%).

In February 2023, the European Commission approved Denmark's EUR 170 million scheme on PtX technologies to support renewable hydrogen production. With the scheme, Denmark aims to introduce 100-200 MW of electrolysis capacity through a public tender that provides a direct grant to the winning companies for a ten-year period.

Figure 10.9 Power-to-X projects and their status in Denmark, 2021



Note: FID = final investment decision.
Source: IEA (2022), Clean Energy Demonstration Projects Database.

Assessment

Denmark has shown leadership in sector coupling. Its strategy to fully decarbonise its economy, aiming at net zero emissions by 2045, relies on electrification. Thanks to the extensive use of co-generation and a district heating network, Denmark already has well-integrated electricity and heat sectors.

Among IEA countries, Denmark has the highest share of district heat in end-use sectors (39%). District heating is the primary source of space heating in the residential sector: nearly two-thirds of Danish consumers receive district heat, or 1.7 million houses and buildings. The commercial sector and industry account for the remaining share of district heat, 30% and 5%, respectively. Overall, district heat relied on renewable sources for 72% of the total.

Whereas historically electricity and heating sector integration was made on the production side with co-generation producing both, coupling on the demand side of the electricity system will become increasingly important. Energy can be stored in large hot water pits. Denmark has several advantages for sector coupling. Consumers are used to hourly electricity prices. As EVs become increasingly available, this could help to charge EVs at the right hours. The same holds for the use of heat pumps in homes. As a consequence of the wide public response to energy conservation in view of the energy crisis, demand from households has become much more flexible. Applications showing hourly prices have become much more common, resulting in a flattened evening peak demand. Changes in market design can ensure that heat pump and EV flexibility is adequately valued by aggregators or suppliers, and that the value is passed on to consumers in the form of lower bills.

In the short term, integration is being pushed to a higher level by leveraging a higher share of renewables in electricity generation and allowing higher electrification of all sectors, as well as leveraging technologies, such as heat pumps, e-boilers, EVs and thermal storage.

The game changer for energy sector integration will come from PtX. Proposals for PtX develop rapidly, but only one connection agreement has been signed. Direct lines might

become a typical Danish solution to connect offshore wind and demand from PtX for the industry at industrial scale. It might also be the case for onshore wind and solar, directly connecting to demand from PtX. This can help the secure integration of such large projects for greater flexibility of the entire energy system.

Denmark expects to become a net exporter of electricity again. There is uncertainty as to where, if and when onshore wind and solar PV will be built and the same holds for offshore wind. Grid planning becomes complex, as the amount of PtX projects rises quickly but the timing of their grid connection remains uncertain.

Denmark is increasingly attracting data centres. Their number is expected to grow from 5 to 60 in the next 10 years. A new balance of risk needs to be found to be able to plan and realise the grid infrastructure in time at the right location, as there is uncertainty about the timing and location of both production and demand.

Experience from other jurisdictions confirms the need for an integrated system plan with different scenarios for future demand and flexibility needs. Such an integrated system plan based on scenarios of demand, production, flexibility and locations will be useful to stay ahead of the green transition with infrastructure and grids and keep production and demand balanced in Denmark as part of a wider region with its neighbouring countries. Potential "backbones" and storages for hydrogen and CO_2, should be included.

Recommendations

The government of Denmark should:

- Support investment and create the necessary framework conditions for future energy system needs and energy sector integration through the design of an export-oriented clean energy supply chain strategy and international industrial net zero partnerships, notably in the North and Baltic Seas.
- Work with neighbouring governments, regulators and system operators to prepare a green infrastructure masterplan which includes major regional projects to progress Denmark's ambition for renewable electricity, CO_2 and hydrogen.

11. Oil

Key data (2022)

Domestic oil production: 64 kb/d, -83% since 2004

Net imports of crude oil:* 86 kb/d, net importer since 2017

Domestic oil products production: 170 kb/d, +23% since 2011

Net imports of oil products: 0.1 kb/d (total imports 20.8 kb/d, total exports 20 kb/d), has been net exporter since 2020

Oil consumption by sector (2021): 135 kb/d (domestic transport 61%, industry including non-energy consumption 21%, international bunkers 13%, buildings 4%, electricity and heat generation 1%)

Share of oil: 34% of energy production, 37% of total energy supply,** 0.9% of electricity generation, 2.0% of heat generation, 36% in total final energy consumption (2021)

* Imports/exports of crude oil includes crude oil, natural gas liquids and feedstock.

** Total energy supply does not include oil used for international bunkering.

Overview

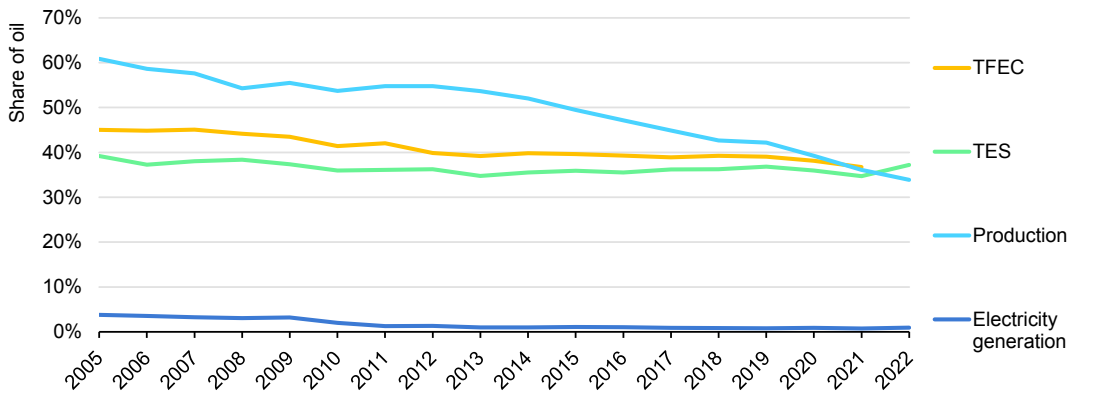
The role of oil remains important for Denmark's energy system but the change in production and consumption will impact the outlook for oil considerably in the coming years. In 2021, Denmark had an oil self-sufficiency rate of 64%, which is very high compared to other EU countries. With the production of crude oil from the Danish fields in the North Sea in decline, crude oil imports to Denmark are rising.

Oil still plays a significant role in Denmark's energy supply mix. In 2022, it accounted for 37% of TES, around the IEA average of 35%. Its share has remained stable over the past decade (Figure 11.1). Over this period, the share of oil in TFEC decreased slightly, from 45% in 2011 to 38% in 2021, driven mainly by consumption changes in the transport sector. The share of oil in Denmark's domestic energy production experienced a significant decline from 55% in 2012 to 34% in 2022. The share of oil in electricity generation has been marginal since 2005, contributing less than 0.9% of the electricity generated in Denmark in 2022.

The Covid-19 pandemic had a stark impact on Denmark's oil demand. Prior to Russia's invasion of Ukraine, in 2021, 17% of crude oil imports and 19% of the import of oil products and 25% of Denmark's diesel imports came from Russia. EU sanctions against imports of Russian oil came into force on 5 December 2022 for crude oil and on 5 February 2023 for

oil products. There have not been any imports of Russian crude oil since the spring of 2022 and Denmark has diversified its imports/exports.

Figure 11.1 Shares of oil in Denmark's energy sector, 2005-2022



Note: Data for TFEC are not available for 2022.
Source: IEA (2023), World Energy Balances.

Supply and demand

Crude oil production and trade

Denmark's crude oil production has been declining since 2004, when production reached 388 thousand barrels per day (kb/d). In 2022, crude oil production amounted to 64 kb/d, an 83% drop compared to 2004 production levels.

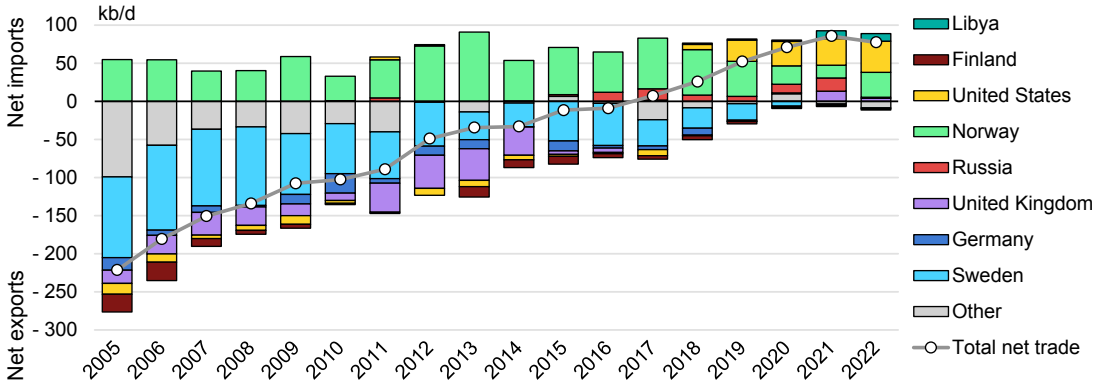
Denmark's position as a crude oil net exporter has been shrinking for many years. In 2017, the country became a net importer (Figure 11.2).

Since 2005, Sweden has been, almost uninterruptedly, Denmark's main importer of crude oil. However, exports to Sweden have declined by 98% in the past decade.

Conversely, Norway has been Denmark's main crude oil supplier. While Norway supplied 86% of Danish imports in 2011, these have fallen considerably since 2019, with the United States becoming a key supplier.

In 2022, due to the impact of Russia's invasion of Ukraine on oil supply, Denmark began to diversify its crude oil import partners away from Russia, which only covered 2% of Danish net imports that year.

Figure 11.2 Denmark's net imports of crude oil and refinery feedstock by country, 2005-2022



Source: IEA (2023), Oil Information.

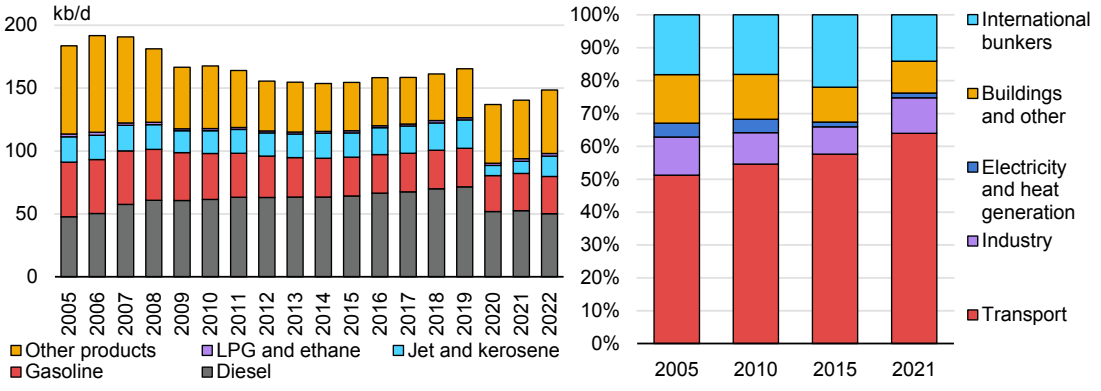
Oil products production, demand and trade

In 2022, total demand for oil products was 150 kb/d (Figure 11.3), slightly below historic averages. From 2012 to 2015, demand for oil products was fairly stable, hovering around 155 kb/d.

Demand for oil products in 2020 and 2021 was considerably lower than the demand registered in the previous decade, due to the impact of the Covid-19 pandemic on the economy. The transport sector was hit particularly hard, registering a drop in diesel demand (-28% from 2019 to 2021) and in jet and kerosene demand (-64% for the same period). Demand for other products, such as gasoil, instead grew over that period (+78%).

In 2021, transport dominated oil products demand (62%), followed by industry (14%), international bunkers (13%), buildings (10%), and electricity and heat generation (less than 1%).

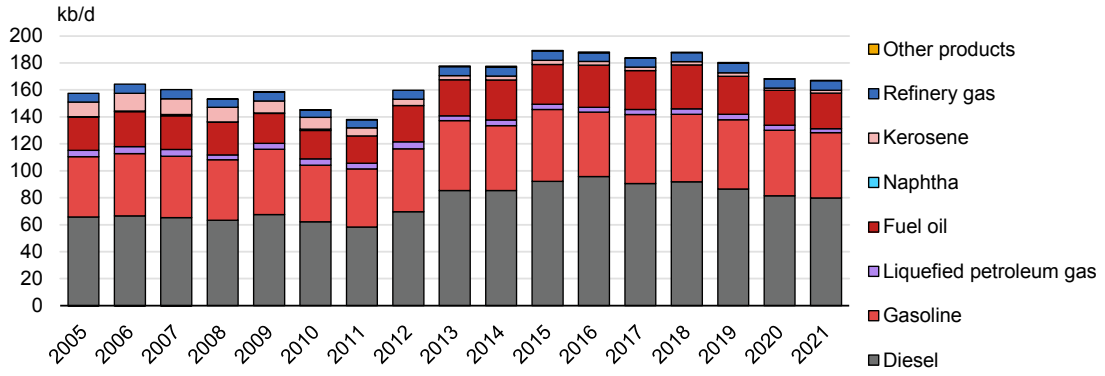
Figure 11.3 Oil products demand by fuel (2005-2022) and sector (2005-2021) in Denmark



Sources: IEA (2023), World Energy Balances; IEA (2023), Monthly Oil Statistics.

From 2011 to 2018, Denmark's total production of oil products increased to reach 188 kb/d (Figure 11.4) but has been falling since, down to 167 kb/d in 2021. Refinery output was dominated by motor fuels, such as diesel (48% of production in 2021) and gasoline (29%), followed by fuel oil (16%), refinery gases (4%), liquefied petroleum gas (LPG) (2%) and kerosene (1%).

Figure 11.4 Oil products production by fuel in Denmark, 2005-2021

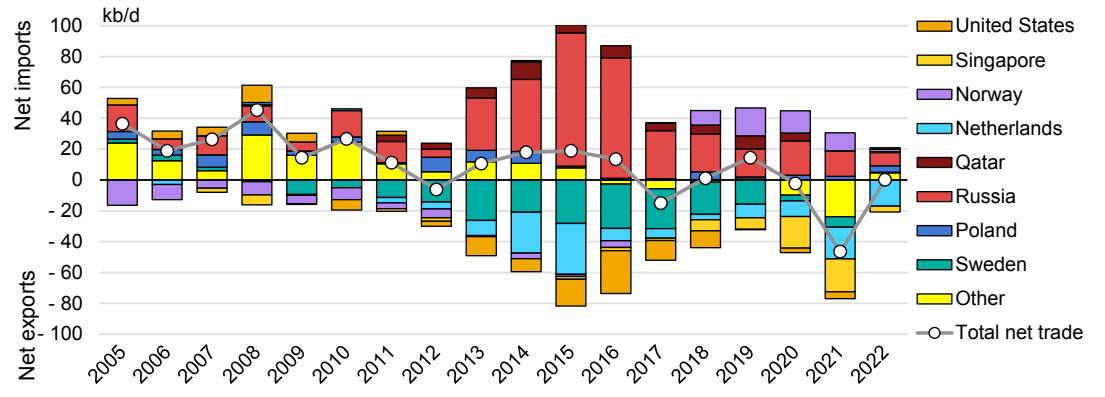


Source: IEA (2023), World Energy Balances.

Over the past decade, Denmark has been shifting from being a net importer to a net exporter of oil products (Figure 11.5). From 2012 to 2016, it was a net importer, with Russia being its main trading partner. The overall volume of oil products traded (imported and exported) has decreased since 2017. In 2017, Russia was the main import partner and Sweden the main export partner.

In 2020, Denmark became a net exporter of oil products. In 2022, exports and imports were almost equal, while oil products were exported to the Netherlands (82%) and Singapore (18%). In 2022, Denmark's net imports came from Russia (41%), followed by Poland (20%), Norway (8%), the United States (4%), Qatar (3%) and Sweden (2%). Net imports from Russia have halved, from 16.3 kb/d in 2021 to 8.5 kb/d in 2022.

Figure 11.5 Denmark's net imports of oil products by country, 2005-2022



Source: IEA (2023), Oil Information.

Oil policy and institutional governance

The main act regulating the Danish upstream oil and gas activities is the Danish Subsoil Act (DSA), which is a framework act. The DSA is supplemented by, *inter alia*, the Danish Continental Shelf Act and the Danish Pipeline Act.

The DSA sets out the basic legal framework for the exploration and exploitation activities concerning raw materials and hydrocarbons in the Danish subsoil and on the Danish Continental Shelf. Several of the DSA's provisions implement EU directives.

The Ministry of Taxation oversees the tax regime applicable to companies engaged in hydrocarbon exploration and production in Denmark. The regime consists of a combination of corporate income tax and hydrocarbon tax combined with a special, temporary hydrocarbon tax allowance from 2017 to 2025, as provided for in the political agreement on the North Sea of 2017.

The Ministry of Finance and the Ministry of Taxation are both responsible for forecasting oil prices, state revenues and the legislation under the Hydrocarbon Tax Act. The DUR sets tariffs for the transport of hydrocarbons applicable to all parties.

The Ministry of Climate, Energy and Utilities oversees the granting of licences and the DEA administers and supervises the licences and permitting. The Geological Survey of Denmark and Greenland is responsible for assessing the geological aspects of the licensing process.

Nordsøfonden is a state company tasked with generating value for the Danish society from the exploitation of Denmark's subsurface assets. Nordsøfonden rests on two pillars: 1) it produces oil and gas, thus helping to secure supplies of energy and raw materials; 2) as a representative of the state, it has a shareholding in all licences for underground CCS.

The Danish Oil Pipe company (disposed to Ørsted company) owns the crude pipeline system in the country including the offshore tie-in platform Gorm "E", a 330 km pipeline across the peninsula of Jutland to crude storage and export facilities adjacent to the refinery in Fredericia. Danske Olieberedskabslagre (FDO) is the central stockholding entity of Denmark. Under the Danish Pipeline Act, the owner, currently Danish Oil Pipe (a subsidiary of Ørsted), operates the pipeline on the Danish Continental Shelf from the Gorm field to Fredericia as well as separation facilities.

In addition to the DEA, the DUR has a supervisory and appeal function in the energy sector. Disputes regarding access to upstream gas pipelines and fees and prices connected hereto are referred to the DUR with recourse to the Danish Energy Board of Appeal.

In accordance with the Statutory Order on Access to Upstream Pipelines, prices, terms and conditions are negotiated between the parties. The overall conditions must not discriminate between applicants and the final agreement, including prices, must be reported to the DUR. The DUR ensures that the owners of the pipelines do not abuse their monopoly rights.

The most relevant environmental laws and regulations applicable to oil and gas activities are the Act on Protection of the Marine Environment, the DSA, the Environmental Impact Assessment Act, the Statutory Order on OIA, the Statutory Order on Alerts Regarding

Pollution of the Sea from Oil and Gas Facilities and Pipelines, and the Statutory Order on Safety Zones and Zones for the Observance of Order and the Prevention of Danger.

The Environmental Protection Agency is the main regulatory authority for environmental integrity in Denmark. It is an agency under the Danish Ministry of Environment. The Ministry is responsible for legislation and is in charge of major national responsibilities as well as particularly complex tasks. The Environmental Protection Agency prepares legislation and guidelines and grants authorisations in several areas.

Licences for offshore projects with a risk of affecting the environment may only be granted and used pursuant to an environmental impact assessment and an impact assessment regarding international nature conservation as well as after consultation with the affected general public, authorities and organisations.

Exploration activities like pre-investigations (e.g. seismic surveys) and drilling may not always require the preparation of an environmental impact assessment or other impact assessment. As a rule, any planned work, including well drilling, shaft sinking, driving adits and drifts, may only be initiated after obtaining prior approval from the DEA.

The future of Danish oil production

In December 2020, a broad majority in the Danish parliament reached an agreement on the future of Danish oil and gas production (North Sea Agreement 2020). The North Sea Agreement 2020 constitutes, *inter alia*: a cut-off date of 31 December 2050 for all oil and gas extraction; a cancellation of the eighth licensing round, all future licensing rounds and the open-door procedure (however, two procedures – the mini-rounds and neighbour-block procedures – still exist but any such permits would still have to adhere to the 2050 date); and a reduction of the geographic area for the issuance of licences. The North Sea Agreement 2020 has been implemented through amendments to the Danish Subsoil Act, which entered into force on 1 January 2022.

A political agreement on the development of the oil and gas sector in the North Sea was agreed upon in 2017. It included a tax relief window during 2017-25 and improved conditions for third-party access to existing infrastructure.

Market overview

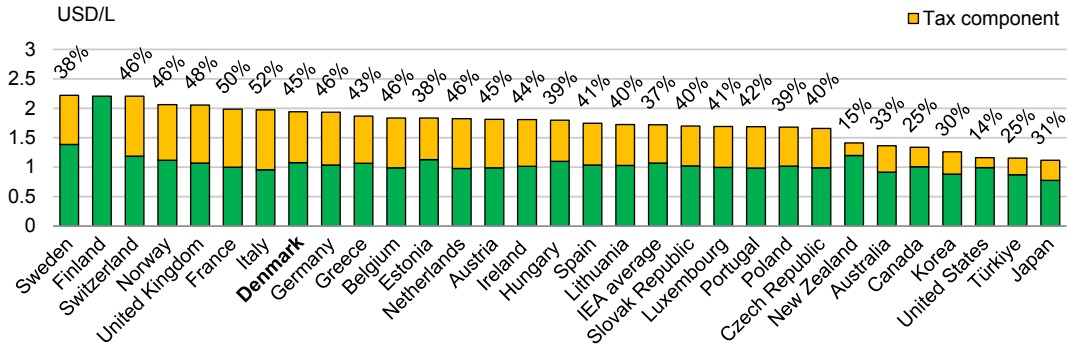
In 2021, Denmark had an oil self-sufficiency rate of 64%, which is very high compared to other countries in the European Union. With the production of crude oil from the Danish fields in the North Sea on the decline, the import of crude oil to Denmark has increased accordingly. In 2021, the Danish oil fields in the North Sea were still the largest single source of crude oil in Denmark. The oil is either transported directly via pipelines to the refineries or shipped from the oil platforms. The US and Norwegian fields in the North Sea are Denmark's second- and third-largest sources of crude oil (imports). More than two- thirds of the Danish imports of oil products in 2021 came from Sweden, Norway and Russia. Sweden alone accounted for a third of Denmark's oil product imports. Imports from countries outside of Europe were mainly of jet fuel.

There are currently 2 000 fuel stations across Denmark, of which 76% are unmanned. In 2021, OK company was the largest owner of gas stations in the country, with 670 locations, followed by the Canadian company Circle K with 226 and Shell with 154. Both refiners and major importers (Shell, Equinor, Circle K, OK), cover over 90% of wholesale fuel supplies.

Prices and taxation

Denmark's automotive diesel prices in the first quarter of 2023 were the eighth-highest in the IEA (Figure 11.6). The price per litre (L) was around USD 1.90, above the IEA average price of 1.70 USD/L. It included a tax rate of 45%, compared with an IEA average tax rate of 37%. Denmark's unleaded gasoline price was the highest among IEA member countries, at around 2.30 USD/L, with a tax rate of 51% (Figure 11.7). The average price for unleaded gasoline among IEA member countries was 1.70 USD/L, with an average tax rate of 44%.

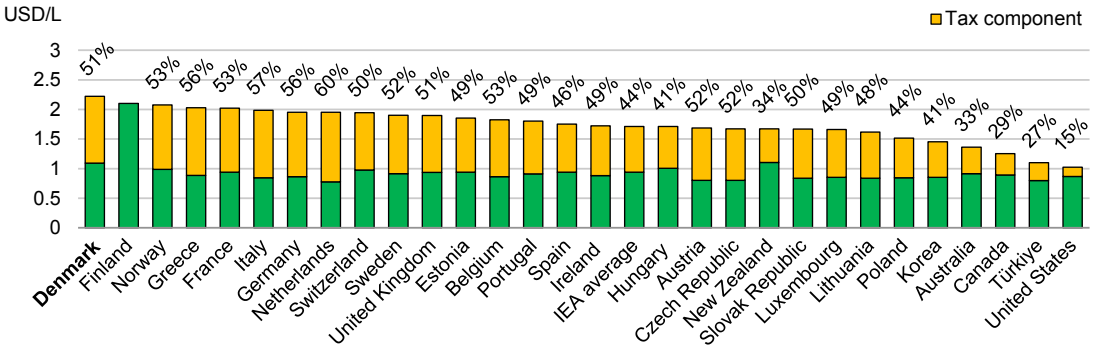
Figure 11.6 Price comparison for automotive diesel in the IEA, Q1 2023



Notes: USD/L = Unted States dollar per litre. Automotive diesel prices are not available for Mexico. Tax information for Finland is not available for Q1 2023.

Source: IEA (2023), Energy Prices.

Figure 11.7 Price comparison for unleaded gasoline (95 RON) in the IEA, Q1 2023

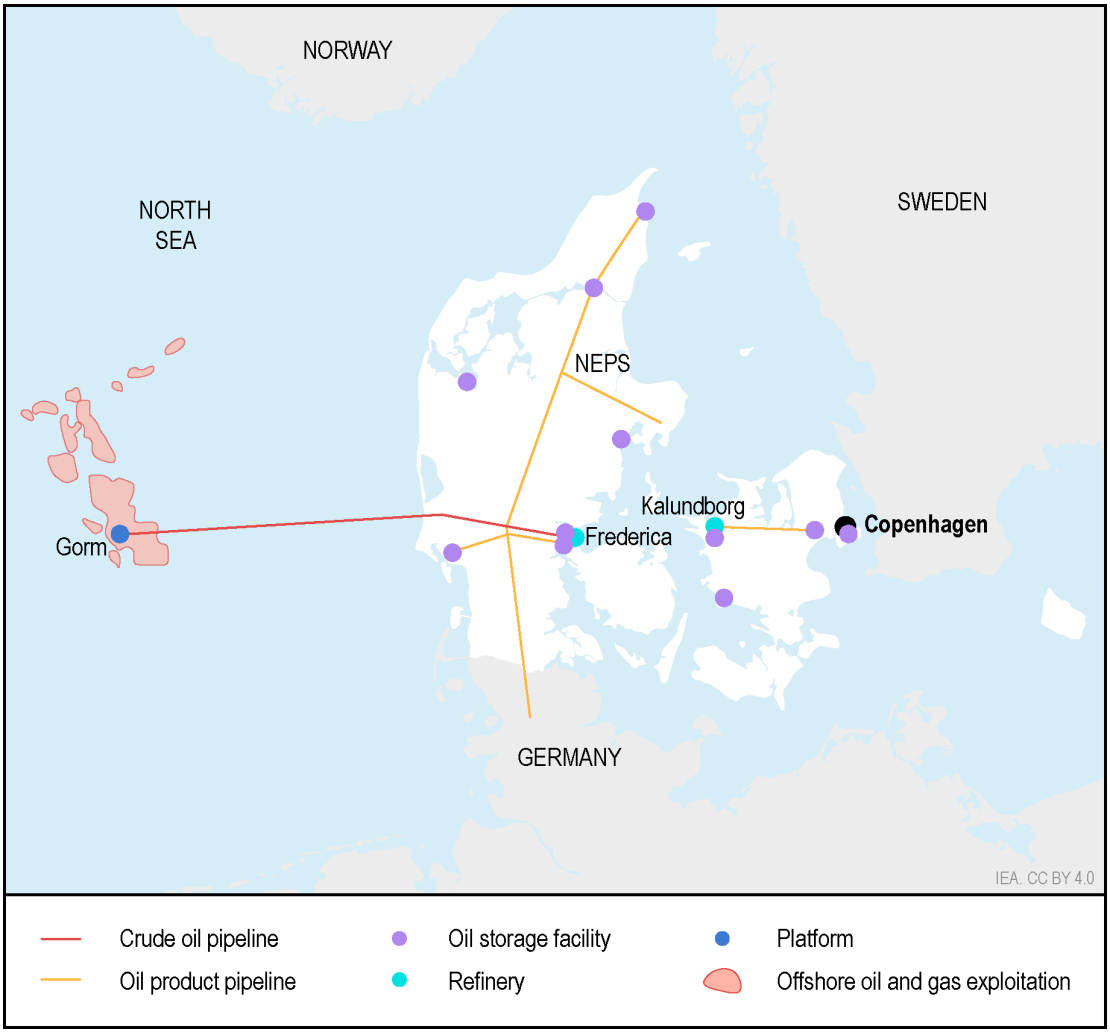


Note: USD/L = United States dollar per litre. Unleaded gasoline (95 RON) prices are not available for Mexico. Tax information for Finland is not available for Q1 2023.

Source: IEA (2023), Energy Prices.

Infrastructure

Figure 11.8 Map of oil infrastructure in Denmark



Refineries

There are two refineries in Denmark. The Kalundborg refinery is the largest in Denmark with 110 kb/d of processing capacity. In addition to the refinery, tanks and port facilities in Kalundborg, the refinery owner also owns two fuel truck loading terminals in Hedehusene and Kalundborg that deliver gasoline, fuel oil and LPG to most of Zealand (Denmark's most populous island). All crude oil and condensate are transported to Kalundborg by ship, and most of the final products are also transported by sea. The refinery in Kalundborg was sold in 2022 by Equinor to Klesch Group, an international industrial commodities group based in the United States.

The second refinery is in Fredericia (Crossbridge Energy Fredericia), with a nameplate capacity of 68 kb/d. It is the world's third-most energy-efficient refinery and number one in Europe, with an announced net zero pledge. It is Denmark's biggest supplier of surplus heat to district heating and delivers what corresponds to the annual consumption of district

heat of 23 000 households. This is achieved by utilising surplus heat from the refinery processes. Furthermore, the refinery plans to conduct pilot projects co-processing bio-based material. It was certified in December 2020 to refine bio-oil products in the existing plant, rather than adding biocomponents afterwards. The refinery produces approximately 35% of the Danish consumption of fuels and exports similar volumes via the company's terminal in Fredericia. In 2021, the refinery in Fredericia was sold to Postlane Partners, an American investment company.

Transportation and storage

The crude pipeline system in Denmark is owned by Danish Oil Pipe company and includes the offshore tie-in platform Gorm "E", a 330 km pipeline across the peninsula of Jutland that connects to crude storage and export facilities adjacent to the Shell refinery in Fredericia. In addition, one crude pipeline is owned by the Danish Underground Consortium transporting crude from the Danish Underground Consortium's (DUC) 13 producing fields to the Fredericia plant.

Transportation of crude is regulated by the Pipeline Act ("Rørledningsloven"), which defines the commercial framework for the operation of the pipeline system and commits Danish Oil Pipe to accept deliveries from any crude producer, however subject to technical feasibility. A potential producer considering investments in production facilities in Denmark should approach Danish Oil Pipe to ensure necessary capacity or, if such capacity is not available, that technical feasibility for transportation can be established. The country has another four product pipelines (three owned by the central stockholding agency and one jet pipeline running to Copenhagen Airport).

Denmark has 16 seaport terminals with a combined import capacity of 52 500 m^3 per day and an export capacity of around 20 000 m^3 per day.

The country has 19 oil storage locations with a combined capacity of 47.7 million barrels, the biggest of which are adjacent to the Fredericia and Kalundborg refineries and in the Stigsnæs/Gulfhavn oil terminal.

Oil security and emergency response

EU Directive 2009/119 obliges Denmark to hold at least 61 days of consumption. Denmark has decided to hold 20% more than the required level, taking into account a 10% reduction for unavailable stocks in the calculation. The country holds emergency stocks equivalent to 81.3 days of average daily inland consumption – exceeding its IEA obligation of 90 days of net imports. EU Directive 2009/119 is implemented into Danish law in the Oil Preparedness Act. The Danish stockholding regime is further regulated in Executive Order No. 1340 of 10 December 2014 about compulsory stockholding obligation.

The Oil Preparedness Act requires a contingency plan to be implemented in the event of a large oil supply disruption. The DEA has developed a plan (Beredskabsplan for oliekriser), which describes the procedures to be followed in the event of an oil crisis. It describes the steps to be taken in the event Denmark has to release oil stocks, put in place consumption-limiting measures and/or allocate oil products to certain groups of users on a priority basis. As most oil consumption is concentrated in the transport sector, short-term fuel switching in an emergency is not seen to be an impactful measure.

In the event of a major supply interruption, the Minister for Climate, Energy and Utilities has the power to decide whether emergency stocks can be released, in accordance with paragraph 19(2) of the Oil Preparedness Act.

The decision can be taken nationally based on an assessment of the national situation and/or the basis of the IEA's and European Union's recommendations. There will typically be close co-ordination with EU member states (Oil Coordination Group) in the event of a collective IEA action. Releasing emergency stocks is a relatively simple process that can be implemented in a short period of time by the DEA in close co-operation with FDO and, if necessary, the companies obliged to hold oil stocks. Nevertheless, Denmark can only release emergency stocks if its own internal market experiences a disruption, which goes against the IEA principle of reacting with oil stocks whenever there is a severe supply disruption for the group.

If there is a decision to release oil stocks, the stock draw will typically be from FDO's stocks, because this type of stock release is considered to have a more immediate effect on the market than a release as part of a reduction in obligated companies' stock levels.

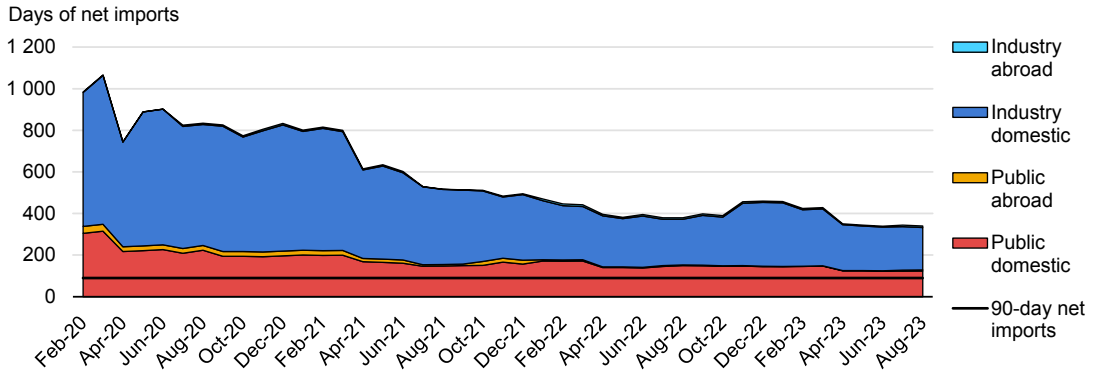
Demand restraint measures

According to the Oil Preparedness Act, the Minister for Climate, Energy and Utilities can impose demand restraint measures in line with the estimated shortages. A catalogue of 20 initiatives has been identified to reduce oil consumption in the transport sector in Denmark. However, the specific situation is taken into account when determining the consumption-limiting measures to be implemented.

Oil stockholding regime

Denmark has consistently maintained oil stocks at a level significantly above the IEA 90-day net imports requirement. As of May 2023, Denmark held stocks equivalent to 344 days of net imports (Figure 11.9). These included 218 days of industry stocks, of which 214 days were held domestically and 4 were held abroad. From the 126 days of public stocks, 124 were held domestically while the remainder was held abroad. Denmark did not join the IEA Collective Actions of March and April 2022.

Figure 11.9 Emergency oil stocks by type in Denmark, February 2020-August 2023



Source: IEA (2023), Oil Information.

Denmark obliges producers and importers of crude oil and refined products to hold 81.3 days of average daily inland consumption. The obligation is calculated based on net sales to end users and non-obligated companies in Denmark. Even companies with no requirement to hold stocks are obliged to report monthly. These companies are known as zero-obligated companies. This reporting helps to strengthen the monthly data reporting system as well as facilitate ticket arrangements with these zero-obligated companies by integrating all oil-related companies under a single reporting system. Around 20-25 companies are considered to hold such zero stockholding obligations out of a total of 40 companies with obligations.

The stockholding obligation is based on the method in EU Directive 2009/119. Only stocks of categories 1, 2, 3 and crude oil count as emergency stocks. The obligation is calculated and defined separately for category 1: motor gasoline and aviation gasoline; category 2: divided into 2A (jet fuel) and 2B (gas/diesel oil); and category 3: fuel oil. The central stockholding entity, FDO, covers 70% of the industry's obligation. The remaining 30% is held in individual companies' (CSO) commercial tanks under obligation. To cover their stockholding obligation, both the central stockholding entity and CSO companies can substitute oil products with crude oil within limitations. Oil products in categories 1, 2A and 2B can substitute each other within limitations, but this does not apply to tickets. The rules ensure that at least 60% of the total obligation is covered by oil products and that fuel oil only covers fuel oil. Both the CSO companies and FDO can cover their part of the obligation (30% and 70%, respectively) using stocks owned by them. They can use international tickets, but CSO companies can only cover 30% of their obligation and FDO can only cover 5% of its obligation. National tickets can be used without restrictions, but only CSO companies and FDO can buy and sell national tickets. Furthermore, CSO companies and FDO must have a surplus of oil in a category once they have covered their own obligation if they want to sell a ticket in that category.

For jet fuel, FDO can cover 100% of its part of the obligation with international tickets. It also holds emergency stocks of jet fuel at Prøvestenen – according to the August 2022 oil data reporting, FDO had 98 700 m^3 of jet fuel in that location (in total it holds about 10% more than its jet fuel obligation).

Denmark has also decided to hold specific stocks in accordance with Article 9 of EU Directive 2009/119. FDO holds specific stocks that consist of gasoline products (category 1) and diesel products (category 2B) for at least 30 days of inland consumption.

Monitoring and compliance

The DEA monitors and controls that FDO and the obligated companies hold emergency stocks. The controls are multiple. The reporting obligation is the most important basis for these controls: FDO and the CSO companies have a monthly reporting obligation and must, on an annual basis, submit an auditor's report that validates the monthly reported data for the whole calendar year.

In accordance with Executive Order No. 424 of 25 April 2018 on Risk Preparedness for the Oil Sector, the DEA also monitors that FDO and the CSO companies have enacted the necessary risk preparedness measures and planning to allow them to release emergency stocks to the market in the case of a larger supply disruption.

Recent supply disruptions

Denmark has not had a major supply disruption in the past years. Higher prices in 2022 due to Russia's invasion of Ukraine led to some tightness, but the market has been adequately supplied at all times. However, the halt of Tyra gas production and in the event of a gas and electricity crisis requiring fuel switching to oil, as well as potential impacts of the sanctions for crude oil from 5 December 2022 and oil products from 5 February 2023 made the oil supply situation tight. In December 2022, an incident halted production of the Crossbridge Energy refinery. Production was partially re-established in January 223 and no oil release was needed.

Assessment

Oil remains important to Denmark's energy supply mix. Nevertheless, the share of oil in TFEC has been decreasing year on year. Two sectors heavily dominate oil consumption in the country: transport (74%) and agriculture (15%).

Denmark's crude oil production has been declining since 2004, when it peaked at 388 kb/d. In 2017, Denmark became a net importer of crude oil. In 2021, it had an oil self-sufficiency rate of 65%, which is very high compared to other countries in the European Union, with Danish oil fields in the North Sea still being the largest single source of crude oil in the country.

Norway has long been Denmark's main source of crude oil imports, although these started to decrease in 2019. Denmark had begun diversifying its crude oil import partners, including Russia. However, all imports from Russia were halted in March 2022 as a response to Russia's invasion of Ukraine and replaced by spot purchases and some additional volumes from Norway.

Total demand for oil products in 2020 (137 kb/d) and 2021 (141 kb/d) showed a considerable drop compared to previous years. This can be explained by the impact of the Covid-19 pandemic on the economy. The transport sector was particularly hard hit: diesel demand fell by 28% from 2019 to 2021 and jet and kerosene demand by 64% in the same period. Oil products production in Denmark had been rising year on year and peaked in 2018 at 188 kb/d. It has since decreased, reaching 167 kb/d in 2021.

Over the past decade, Denmark has been swinging from being a net importer to a net exporter of oil products. In 2022, it was a net exporter. In 2021, Denmark's diesel imports from Russia accounted for 25% of total diesel imports but imports were halted in March 2022. The EU-wide embargo of oil products imports from Russia effective since 5 February 2023 may still have an impact on Denmark, both in terms of price volatility and/or strains to supply.

Following Russia's invasion of Ukraine, the Danish government committed to a complete phase-out of Russian oil imports. Previously heavily reliant on Russian crude oil, Denmark has made commendable efforts to halt crude oil imports from Russia by sourcing alternative supplies.

Denmark has biocomponents targets of 3.5% for 2023 increasing to 7% in 2030. This is relatively low by international standards. The government should study the benefits of further increasing the blending targets for biocomponents, including advanced biofuels, especially as this would help reduce oil demand and gradually phase out fossil fuels, particularly in the transport sector.

After the Russian invasion of Ukraine in 2022, the Danish government announced that it would look into increasing its oil and gas production over a short term to help international markets, although this proved to be unsuccessful, mainly because the biggest offshore producing field in Denmark, the Tyra complex, was shut down in 2019 and its recommissioning postponed by over two years compared to the initial plans, meaning that it will not come online before the beginning of 2024. Denmark should assess whether there are any measures that could be taken swiftly to contribute to easing current market tightness due to Russia's invasion by bringing additional barrels to market.

There are two refineries in Denmark. The Kalundborg refinery is the largest in Denmark, with a processing capacity of 110 kb/d. In addition to the refinery, tanks and port facilities in Kalundborg, there are two fuel truck loading terminals in Hedehusene and Kalundborg that deliver gasoline, fuel oil and LPG to most of Zealand (Denmark's most populous island). The refinery in Fredericia (Crossbridge Energy Fredericia), with a 68 kb/d processing capacity, is the world's third-most energy-efficient refinery and number one in Europe, with an announced net zero pledge and plans to gradually transform it into a biorefinery. It was certified in December 2020 to refine bio-oil products in the existing plant, rather than adding biocomponents afterwards. The plant is also Denmark's biggest supplier of surplus heat to district heating. It delivers the equivalent of 23 000 households' annual consumption of district heating.

The government has also announced the possibility of electrifying offshore oil and gas production in Denmark, with the Tyra field reconstruction being a plug-in ready standard. The government should continue exploring how to better incentivise the electrification of current offshore oil and gas production, which can lower the industry's carbon footprint and support the government's climate agenda.

In December 2020, a broad majority in the Danish parliament reached an agreement on the future of Danish oil and gas production (North Sea Agreement 2020), which introduced a cut-off date of 31 December 2050 for all Danish oil and gas extraction. The Agreement also cancelled the eighth licensing rounds which were ongoing at that time, all future licensing rounds and the open-door procedure for production licences; and reduced the geographic area for issuing licences. Within the spirit of the North Sea Agreement, and while transitioning away from oil and gas production, the government should ensure that it incentivises industry to fully develop the remaining potential.

Recommendations

The government of Denmark should:

- Thoroughly assess to what extent existing offshore production of the Danish Continental Shelf can bring additional volumes of oil to international markets over the short run to alleviate tensions caused by Russia's war on Ukraine, without compromising Denmark's ambitious climate goals.
- While implementing the 2020 North Sea Agreement, ensure sufficient signals for industry to develop the remaining potential, while transitioning to green business options and ensuring compliance with the highest decommissioning standards.
- Assess the possibility to increase blending targets for biocomponents, including advanced biofuels, to contribute to greening the transport sector.
- Study the potential of electrification of offshore production to support the country's climate agenda.

12. Natural gas

Key data (2022)

Natural gas production: 2 bcm; -76% since 2012

Net imports: 0.5 bcm (2.8 bcm imports, 2.3 bcm exports)

Gas consumption by sector (2021): 2.5 bcm (industry 45%, buildings 34%, electricity and heat generation 21%)

Share of natural gas: production 13%, TES 9%, heat generation 7%, electricity generation 3%, total final energy consumption 12% (2021)

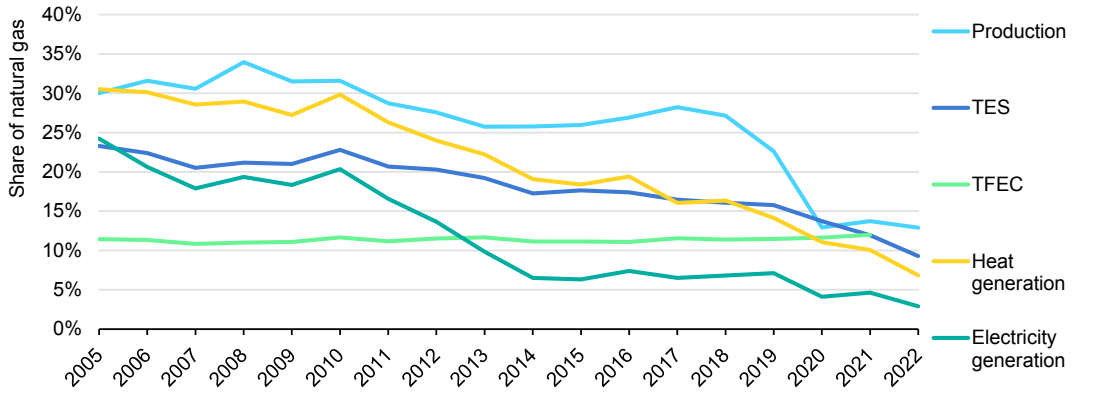
Overview

Natural gas does not play a very significant role in Denmark's energy system. The policy objective is to fully phase out natural gas, with the political ambition of ending individual gas heating in households by 2035 and using 100% green renewable gases "by the latest" in 2030. Denmark will no longer be extracting natural gas from the Danish part of the North Sea in 2050.

By amending the Subsoil Act in 2019, the government legislated the end of new major oil and gas exploration on land and in inner territorial Danish waters through new licences. Under the 2020 North Sea Agreement, companies are still allowed to apply for new licences for drilling in a few existing fields and for exploration of small new fields. Mini auction rounds are possible for new fields and neighbouring blocks (for areas neighbouring existing licences when the geologic structures holding the oil or gas are known to cross over or be connected beyond the licence area).

Over the past two decades, Denmark's natural gas production has declined (from 30% in 2005 to 13% in 2022). The role of natural gas has also decreased in heat generation (from 31% to 7%), total energy supply (from 23% to 9%) and electricity generation (from 24% to 3%). TFEC remained stable in 2021 at 12% (Figure 12.1).

Figure 12.1 Shares of natural gas in Denmark's energy system, 2005-2022

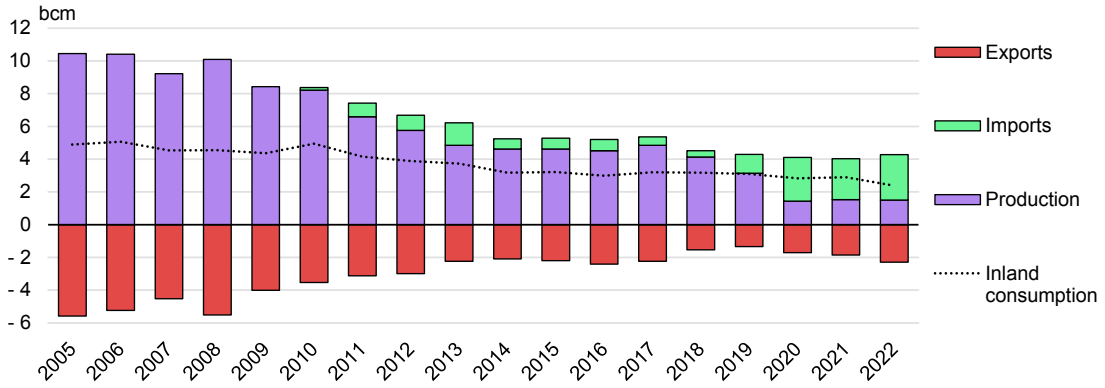


Note: TFEC data are not available for 2022.
Source: IEA (2023), World Energy Balances.

Gas supply, demand and trade

Natural gas production has declined by 74% over the past decade and stood at 2 billion cubic metres (bcm) in 2022 (Figure 12.2), with a substantial drop in 2020 due to redevelopment of the Tyra offshore complex. Tyra is expected to deliver 2.8 bcm after its renovation when it is gradually back online in the winter of 2023/24. This volume corresponds to the domestic gas demand in 2021.

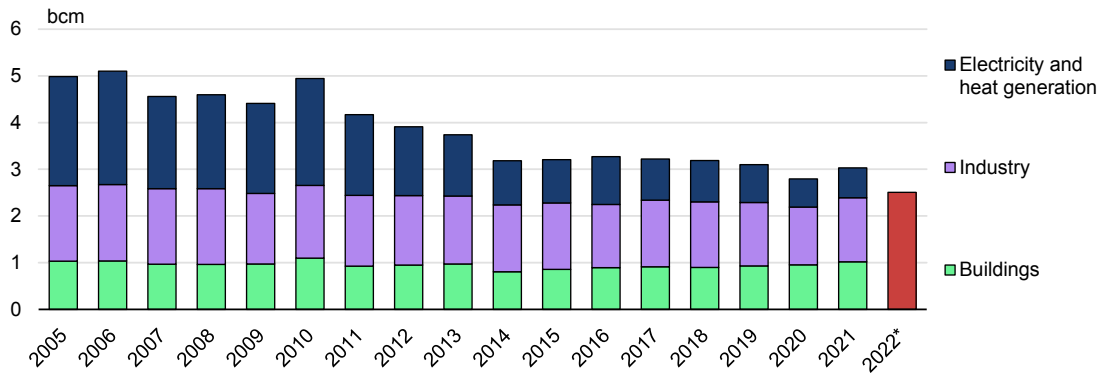
Figure 12.2 Natural gas supply by source in Denmark, 2005-2022



Note: bcm = billion cubic metres.
Source: IEA (2023), World Energy Balances.

In 2022, Denmark's total natural gas demand was 2.5 bcm. In 2021, its demand for natural gas came from industry (44%), followed by buildings (34%), electricity and heat generation (22%), and transport (1%) (Figure 12.3). From 2011 to 2021, demand for natural gas from electricity and heat generation decreased by 63% and by 10% for industry. Demand from buildings has remained steady over time, around 0.9 bcm.

Figure 12.3 Natural gas demand by sector in Denmark, 2005-2022



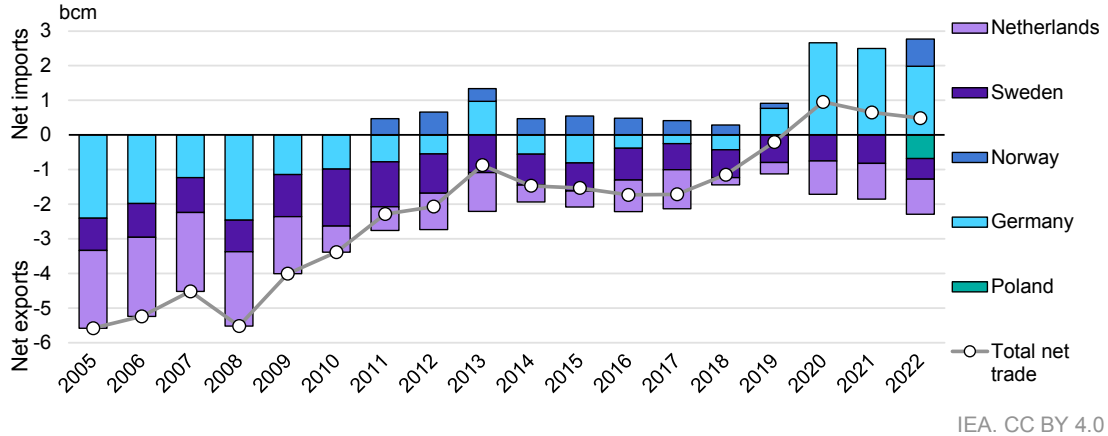
* Breakdown by sector not available for 2022.

Source: IEA (2023), World Energy Balances.

Denmark was a net exporter of natural gas until 2019 then became a net importer in 2020 (Figure 12.4). Denmark has traditionally exported gas to the Netherlands, Sweden and Germany. In both 2020 and 2021, Denmark exported gas to the Netherlands and Sweden while importing significant volumes from Germany. With the Baltic Pipe coming onstream, in 2022, Denmark started to export natural gas to Poland and increased imports from Norway.

The Tyra field (operated by Total Energies), securing more than 90% of Denmark's domestic gas consumption, has been undergoing a complete reconstruction since 2019. This has meant a temporary halt to production from the field. Originally set to resume operations in 2022, various challenges have put a curb on the development of the reconstruction project (with costs of DKK 21 billion, or EUR 2.82 billion). The Tyra field is expected to be recommissioned at the beginning of 2024.

Figure 12.4 Denmark's natural gas net imports, 2005-2022



Source: IEA (2023), World Energy Balances.

Market structure

The Danish gas market is governed by the Natural Gas Supply Act of 1979 with all the subsequent amendments (the most recent in 2020). The DEA is responsible for the Act and oversees its implementation.

The country's gas market has been fully liberalised since 2004. There are around ten natural gas suppliers which offer their customers different products. Most of the products are traded on the gas market and prices are set according to the available offers. The Danish gas market model offers shippers two ways to buy and sell gas through: 1) the virtual point Exchange Transfer Facility for trade executed on the Danish gas exchange, Pegas; and 2) the Gas Transfer Facility, the virtual point for bilateral trade in the secondary market.

Customers who have not decided where they want to receive their gas from are supplied from a universal service company at a set price which is regulated by the DUR. This service is most commonly used by small companies and households.

Consumers can easily get information about switching supplier on a publicly accessible website (http://gasprisguiden.dk).

Gas transmission system

Denmark's gas infrastructure plays a pivotal role for regional natural gas security as it connects the Dutch, German, Polish and Swedish gas systems to the wider European system with Norwegian gas resources. Opened in 2022, the Baltic Pipe from Norway serves gas markets in Poland and neighbouring countries. The Baltic Pipe has the capacity to transport up to 10 bcm per year from Norway to Poland and can transport 3 bcm of gas from Poland to Denmark through reverse flow if needed. Denmark does not have liquefied natural gas facilities. The Danish gas system is part of the overall European gas system and gas market.

The transmission system in Denmark has a total length of 900 km and is owned and operated by the TSO, Energinet (which is owned by the Danish Ministry of Climate, Energy and Utilities and also operates the electricity grid).

The transmission system also provides access to two Danish gas storage facilities, owned by the TSO. The gas storage facilities are used to compensate for seasonal fluctuations in consumption and for commercial purposes to reduce gas price differences. They are also used as a tool to maintain security of supply.

Gas distribution system

The Danish distribution system is owned and operated by the three distribution companies that merged into one company, Evida, as of 1 January 2023. Evida is owned by the Danish Ministry of Finance.

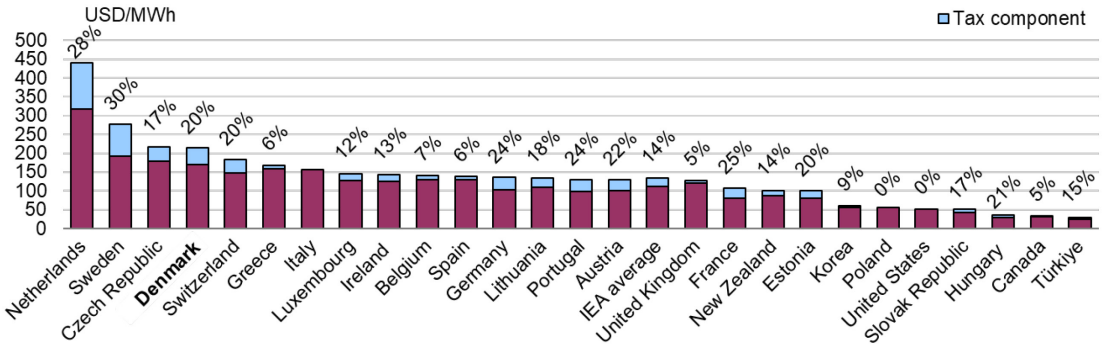
The distribution system has a total line length of about 17 000 km and is connected to more than 400 000 supply points. In Copenhagen, Frederiksberg and part of Aalborg, there is also a network which supplies consumers with so-called town gas.

While the TSO and DSOs decide their respective tariffs, the DUR approves the method for setting the tariffs and approves them.

Prices and taxation

In Q4 2022, natural gas prices for households in Denmark were the fourth-highest among IEA countries at an average of 213.7 USD/MWh with a tax rate of 20% (Figure 12.5). In comparison, the IEA average price was 134.6 USD/MWh, with an average tax rate of 14%.

Figure 12.5 Natural gas prices for households in the IEA, Q4 2022

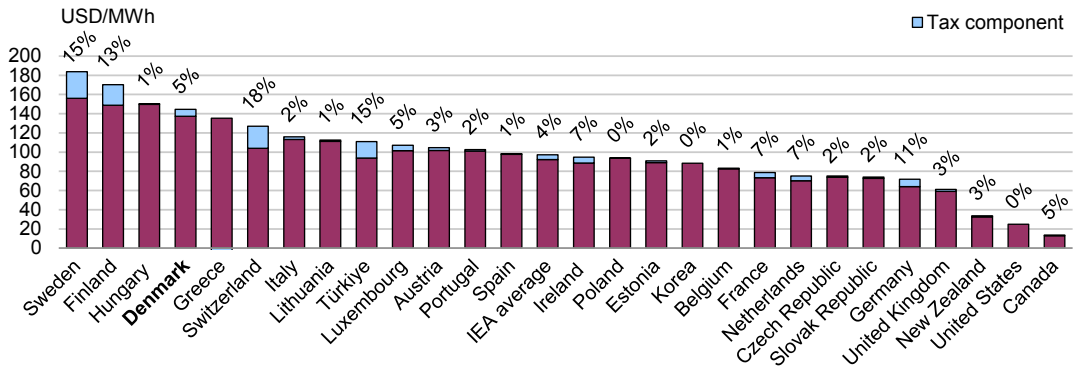


Notes: USD/MWh = United States dollar per megawatt hour. Household prices are not available for Australia, Finland, Japan, Mexico or Norway and tax information is not available for Italy.

Source: IEA (2023), Energy Prices.

In Q4 2022, natural gas industry prices in Denmark were the fourth-highest among IEA countries at 144 USD/MWh, with a tax rate of 5% (Figure 12.6). By comparison, the IEA average price was almost 100 USD/MWh, with an average tax rate of 4%.

Figure 12.6 Natural gas prices for industry in IEA countries, 4Q 2022



Notes: Industry prices are not available for Australia, Japan, Mexico or Norway and tax information is not available for Greece.

Source: IEA (2023), Energy Prices.

Customers have access to three products: 1) a universal service product; 2) a basic product; and 3) a gas market product. The first two products are regulated by the DUR.

Denmark is divided into three geographical universal service areas where customers can choose a universal product from a company which delivers the product at a set price. The right to deliver the universal service product has been granted through a public tender. The existing universal service obligation ran until 31 March 2023. It will be replaced with a delivery obligation product, where all companies must have the product instead of one company with the universal service product.

Natural gas policy and regulation

Denmark's natural gas policy has a clear objective of accelerated phasing out of natural gas following political ambitions in the political agreement from June 2022 (Climate Agreement on Green Electricity and Heating), which sets a political ambition of having 100% green renewable gas by 2030 at the latest and a political ambition of phasing out individual natural gas heating in households in 2035.

The gas market is regulated through the 2020 Danish Natural Gas Supply Act, which stipulates the roles and responsibilities for transmission, distribution, supply and storage of gas and the use of renewable gases in the natural gas system. It also stipulates the role and responsibilities of the TSO and DSOs.

Danish gas sector institutions are, in general, centralised and are under the instruction of the Minister for Climate, Energy and Utilities. The regulation of gas production and distribution is managed by the DEA, a subsidiary body of the Ministry.

According to the 2020 North Sea Agreement, by 2050, fossil natural gas will no longer be extracted from the Danish part of the North Sea.

Over the past three years, the government has announced strategies, political agreements and funding to support CCS and PtX. Cost-effective solutions are likely to include the creation of a transport pipeline to connect to sources of CO_2 as other transport modes are likely to be costlier. Denmark is targeting storage of 4.5-9 Mt CO_2 from large emitters in Denmark and has a vision to become a European hub for CCS. As the economics of CCS generally improve with scale, any transport pipeline would likely include connections to neighbouring countries with CO_2 sources, including potentially Germany. CO_2 can be transported in converted natural gas pipelines with little additional investment.

PtX will use power to create e-fuels by using electrolysers to produce hydrogen from water but can involve the transformation of the hydrogen into ammonia or methanol, both of which can be used to make other products, including fertiliser and e-fuels. As hydrogen is the basis, depending on the economics, a hydrogen pipeline would facilitate the transport of hydrogen from production sites onshore or offshore to usage that could include industrial users for high heat purposes or chemical transformation. Hydrogen can be blended and injected into natural gas pipelines with significant investment in coating and additional compression. As Denmark has insufficient heavy industry needing high heat uses compared to the likely volume of production of hydrogen based on announced projects, an international hydrogen pipeline may be needed.

In 2023, Denmark decided to allocate responsibility for hydrogen transmission networks to Energi.net and the task of hydrogen distribution to Evida, the gas distribution company.

CO_2 and hydrogen pipeline projects involve substantial commercial risks that need to be mitigated to enhance financial viability. Both rely on a carbon price to incentivise demand for the transport pipeline (carbon sequestration and hydrogen usage, respectively). The relevant carbon prices are determined by policy that is set at both the EU and national levels. As there is no substantial market for both products today, pipeline development cannot rely on existing demand. That demand, in turn, requires investments to be co-ordinated with decisions by multiple carbon emitters and project developers, respectively, to invest in CCS and hydrogen production.

Box 12.1 Denmark and the European hydrogen backbone

By 2030, initial development of the Danish backbone consists of newly constructed hydrogen pipelines and the repurposing of an existing natural gas pipeline, connecting large-scale hydrogen producers and industrial clusters with large-scale storage facilities and export opportunities though the interconnection with Germany.

By 2035, Denmark seeks to draw upon its significant offshore wind resources in combination with electrolysis to attract new industries, such as e-fuels. The energy islands together with the build-out of large-scale onshore photovoltaics will be the drivers for the expansion of the national hydrogen infrastructure, which in the west expands into the North Sea, enabling offshore hydrogen production at the energy island.

The eastern route is meanwhile extended by connecting the Copenhagen area with Sweden and through a new transmission pipeline that could be constructed from the Copenhagen area southwards towards Germany.

By 2040, the east and west backbones are connected across Denmark by repurposing the Baltic Pipe, which is further extended towards Poland to enable a supply connection. A northern connection from Jutland towards demand areas in Sweden also emerges. In the North Sea, a hydrogen interconnector is established between the Danish energy island and the Dutch offshore hydrogen production in area six, thus enabling the export of hydrogen produced offshore.

The 2030-40 plans include developments for hydrogen transport, which will co-exist with the biomethane grid. What specific pipeline developments are realised depends on the societal economic value and demand situation in the future.

Source: European Hydrogen Backbone (n.d.), Country Narratives: Denmark.

Upstream

The main act regulating the Danish upstream oil and gas activities is the Danish Subsoil Act, which is a framework act. The DSA is supplemented by, *inter alia*, the Danish Continental Shelf Act and the Danish Pipeline Act.

The DSA sets out the basic legal framework for the exploration and exploitation activities concerning raw materials and hydrocarbons in the Danish subsoil and on the Danish Continental Shelf. Several of the DSA's provisions implement EU directives.

The tax regime applicable to companies engaged in hydrocarbon exploration and production in Denmark consists of a combination of corporate income tax and hydrocarbon tax combined with a special, temporary hydrocarbon tax allowance from 2017 to 2025 from the North Sea Agreement of 2017 (Ministry of Taxation), amounting to 68% in total.

Nordsøfonden is the Danish state company tasked with generating value for Danish society by exploiting the potential of Denmark's subsurface assets. Nordsøfonden is owned by the state through the office of the Minister of Industry, Business and Financial Affairs and is administrated by Nordsøenheden, which is an independent state-owned company.

DUC is a joint venture involving TotalEnergies (43.2%), Norwegian Energy Company Noreco (36.8%) and Nordsøfonden (20%). The companies work together to produce oil and gas from the 13 producing fields in the Danish part of the North Sea. TotalEnergies is the operator and is responsible for the exploration and operation of DUC's 13 producing fields. DUC accounts for 90% of the Danish oil and gas production and owns key parts of the infrastructure in the Danish section of the North Sea.

Oil and natural gas production remains a significant source of methane emissions, although lower than agriculture and waste. Electrification of more recent offshore production platforms would replace gas usage, reduce gas leakage, allow for greater capture of vented methane and therefore reduce methane emissions. In March 2023, Denmark put forward legislation to reduce methane emissions from oil and gas production. In April 2022, the government published a report on possibilities for the electrification offshore platforms.

Biogas

In 2023, Danish gas consumption is expected to consist of 35% biomethane and 65% natural gas, according to the DEA's projections.

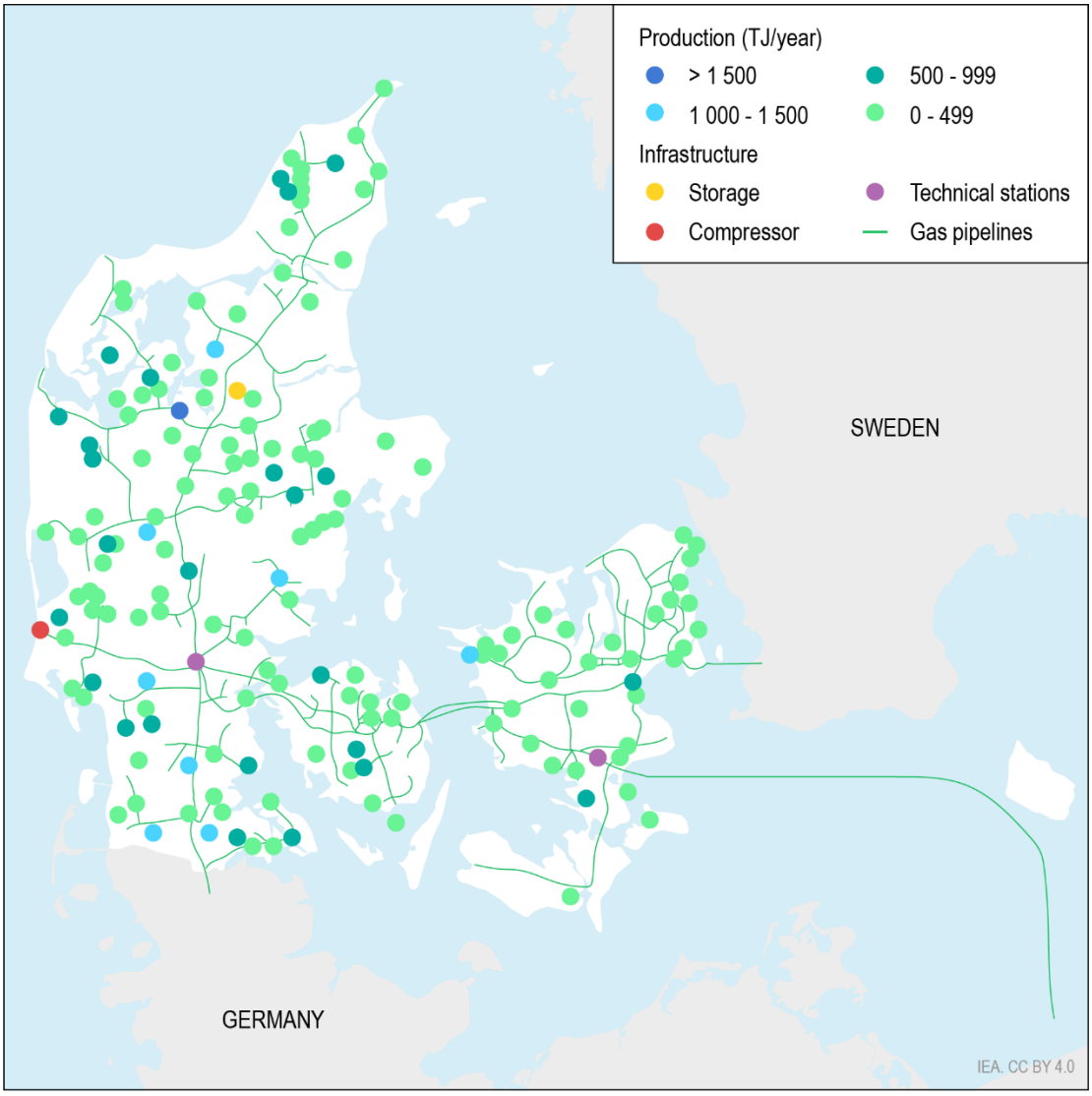
Denmark currently counts around 70 large biogas producers (injecting to the distribution grid). Biogas is generally produced at industrial-scale facilities primarily in Jutland that use a variety of agricultural wastes and products. Biogas plants typically send their gas through distribution networks, but some biomethane is sent via the gas transmission pipelines. Because the biogas is provided at low pressure, compressors are needed to allow it to enter the transmission network.

New tenders for the production of biogas and other green gases based on a competitive bidding process were politically agreed upon in 2020. The first tender was designed as a feed-in tariff support scheme for the production of biomethane and e-methane injected into the gas system. The budget for this measure is DKK 13.6 billion for 20 years. Due to the energy crisis in Europe, on 25 June 2022, it was decided to move forward one tender to 2025 that was originally planned to take place in 2026. The planned state aid tenders for the production of biomethane are expected to entail the establishment of an additional 10-15 biogas plants that will be connected to the gas system by 2030.

The Climate Agreement also includes a planned closure or conversion of parts of the gas distribution network for the transport of renewable gases. The need to accommodate decentralised gas production will continue to rise as gas is increasingly produced at biogas plants around Denmark. This need will become especially relevant once the production of biogas in a given distribution area exceeds the level of consumption in that area, and it is expected to be handled primarily through the construction of several return facilities that can bring the gas up to a higher pressure level transmission grid. However, no decisions have been yet taken on this.

The Energy Crops agreement from June 2021 significantly lowers the limit for the use of energy crops as part of biogas production and bans the use of corn as an energy crop from August 2025 onwards. A later agreement from April 2022 temporarily maintained the current limit of 12% energy crops content until 31 July 2023. Since August 2023, the limit has been lowered to 6%. From August 2024, it will be further lowered to 4%.

Figure 12.7 Biogas infrastructures in Denmark



Natural gas infrastructure

Denmark's gas infrastructure plays a pivotal role for regional natural gas security as it connects the Dutch, German, Polish and Swedish gas systems to the wider European system with Norwegian gas resources. Opened in 2022, the Baltic Pipe from Norway serves gas markets in Poland and neighbouring countries. It has the capacity to transport up to 10 bcm per year from Norway to Poland and can transport 3 bcm of gas from Poland to Denmark through reverse flow if needed. Denmark does not have liquefied natural gas facilities.

The Danish gas system consists of gas production facilities and pipelines in the Danish part of the North Sea, a transmission system and distribution systems. Moreover, the gas system consists of a gas treatment facility (in Nybro), two underground storage facilities and a compressor station (in Egtved, constructed to enable gas to be transported from Germany to Denmark). The Danish gas system has three physical entry/exit points (Nybro, Ellund and Dragor) where gas can be supplied to or from the Danish gas market. Furthermore, there are a number of virtual entry/exit points for gas traded within the system (bilateral contracts or gas exchange) and for upgraded biogas (bio-natural gas).

Pipelines

Baltic Pipe

The Baltic Pipe carries gas from Norway through Denmark to Poland and neighbouring countries. The Baltic Pipe will make it possible to import up to 10 bcm of gas annually from Norway to Poland and to transport 3 bcm of gas from Poland to Denmark. The physical gas transmission started on 1 October 2022, and the Baltic Pipe was fully commissioned in November 2022.

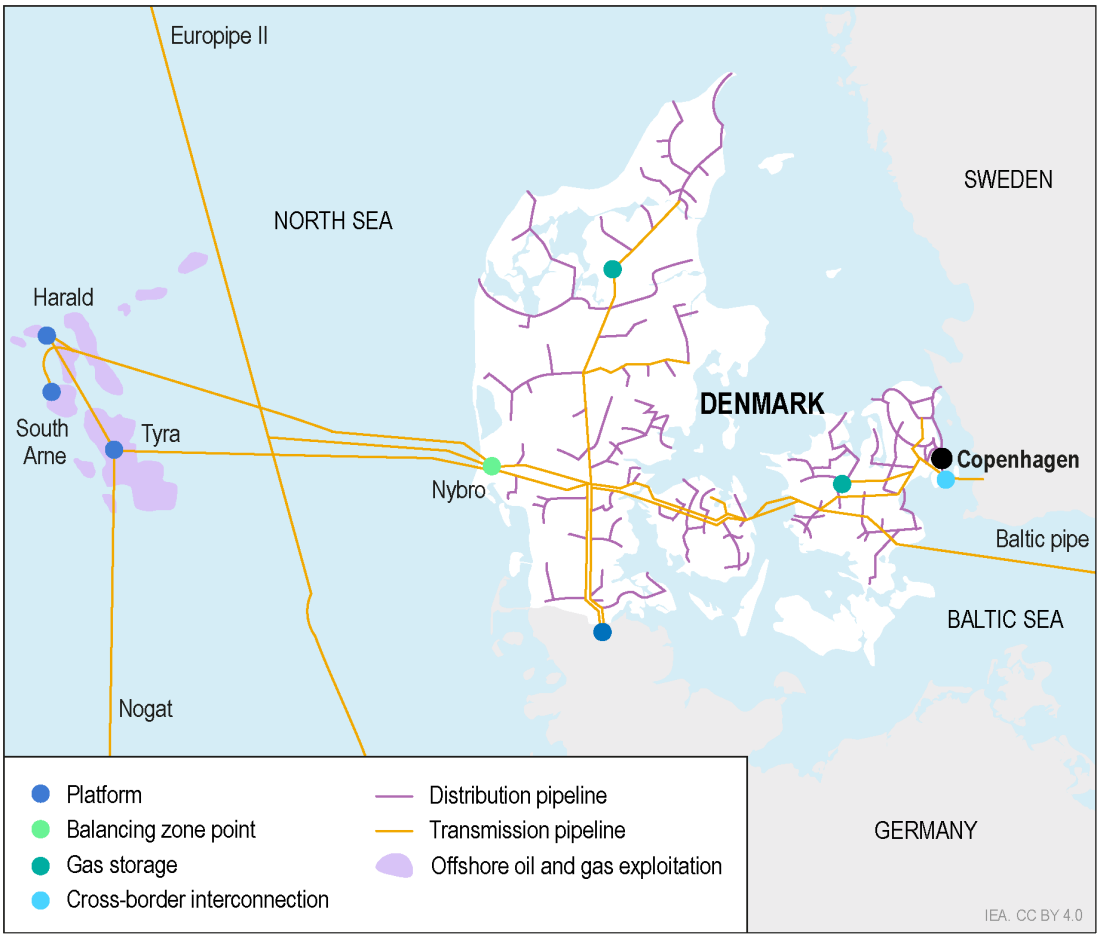
"Green Gas to Lolland-Faster"

The TSO (Energinet) and DSO (Evida) have started preparations to build a new gas pipeline between South Zealand, Falster and Lolland (the "Green Gas to Lolland-Falster"). The pipeline is expected to be finished in 2024. The previous government decided that the gas pipeline must be built to ensure that companies on Lolland and Falster, including Nordic Sugar's two large sugar factories, can reduce their CO_2 emissions. The gas pipeline will contribute to preserving local businesses and jobs and promote the expansion of local biogas production in Lolland and Falster. Today, there is no gas infrastructure for Lolland and Falster, which hampers the construction of local biogas plants.

Danish North Sea pipelines

In the Danish part of the North Sea, gas pipelines to Nybro connect the gas production to Jutland in Denmark. Danish gas exports to the Netherlands are carried through the Tyra-Nogat pipeline, which provides Denmark with an additional export route, enabling greater sales flexibility. The pipeline system on the Danish Continental Shelf is connected to the Nogat pipeline system via the Tyra West – F3 pipeline. This 100-kilometre long natural gas subsea pipeline connects the Danish Continental Shelf with the Dutch Continental Shelf, thus facilitating the export of Danish gas to northwest Europe.

Figure 12.8 Natural gas infrastructure in Denmark



Storage

Denmark has two gas storage sites operated by a subsidiary body of the TSO – Stenlille aquifer and Lille Torup salt caverns. In 2022, national storage capacity was expanded from around 9.2 TWh to 9.9 TWh, sufficient to cover over 30% of Denmark's annual gas consumption, as well as neighbouring countries' needs. The gas storage facilities are used to compensate for seasonal fluctuations in consumption and for commercial balancing purposes to reduce gas price differences. They are also used as a tool to maintain security of supply.

Natural gas security and emergency response

Natural gas emergency response policies in Denmark are underpinned by the TSO's 2018 Risk Assessment, the Preventive Action Plan and the Emergency Plan for the Danish Gas Transmission System.

Protected consumers are households, captive district heating installations (provided that they are not able to switch to other fuels), and SMEs. The TSO determines a threshold for protected consumers in order to comply with EU Regulation 1938/2018.

The Danish emergency plan states that Energinet has to supply protected consumers for up to 60 days (minimum of 30 days) during a normal winter (corresponding to the expected repair time needed after the breakdown of an offshore pipeline or Bybro treatment facility) and for three days during particularly cold periods (defined as a daily mean temperature of -13°C). Non-protected consumers will also be covered for up to three days in a supply emergency.

To meet this security objective, all gas storage users must hold a minimum level of gas stocks for winter and Denmark achieved a 95% filling ratio before the winter of 2022/23 according to the EU regulations following the Russian invasion of Ukraine.

The TSO has signed contracts with commercially interruptible consumers in Denmark and Sweden. These interruptions may be activated when declaring an alert or emergency level.

In cases where Denmark is affected by major crises and incidents, such as explosions, power cuts, accidents or attacks, the national operational staff – NOST – manage and co-ordinate the operational efforts across the authorities. The staff is led by the National Police and consists, in addition to the National Police, of the Police Intelligence Service, the Defence Intelligence Service, the Defence Command, the National Emergency Management Agency, the Ministry of Foreign Affairs, the Agency for Security of Supply, the Danish Health Agency and the Danish Transport Agency. Other authorities may be called on as necessary in relation to the nature of the incident. NOST members meet physically several times a day both before, during and after an incident and prepare and co-ordinate the operational efforts until the emergency or incident is reduced.

Given that the offshore Tyra gas field in the North Sea has been shut down since September 2019 and will not reopen before the beginning of 2024, the TSO arranged during this three-year-period for consumers in Denmark and Sweden to primarily get their gas supply from Germany, biogas and the Danish gas storage facilities. Since the opening of the Baltic Pipe in 2022, Norwegian gas has become another source of supply.

Assessment

Denmark is significantly reducing its consumption of natural gas, having already replaced more than one-third of it with biomethane. At the same time, the country plays a key role in securing the supply of natural gas to the region through its gas infrastructure.

The policy objective is to phase out natural gas, with an ambition of ending individual gas heating by 2035 and using 100% renewable gases by 2030 at the latest, while no longer extracting natural gas from the Danish part of the North Sea by 2050. Relying entirely on biomethane requires adequate infrastructure, including a suitable number of compressor stations and distribution networks to inject the increased biogas into the grid after purification.

Through the 2019 amendment of the Danish Subsoil Act, the government closed oil and gas exploration on land and in inner Danish waters as well as the possibility to issue new licences. Under the 2020 North Sea Agreement, applications are still, however, allowed for new licences for drilling in a few existing fields as well as the possibility to apply for exploration in new areas (through mini-rounds for new fields and for areas neighbouring existing licences).

As oil and natural gas production remains a significant source of methane emissions, although lower than agriculture and waste, and in view of its ambitious net zero targets, the Danish government has taken action and introduced financial and policy incentives to encourage the electrification of offshore oil and gas production.

Over the past three years, the government has announced strategies, political agreements and funding to support CCS and PtX projects for Denmark to become the European hub for CCS and for hydrogen production. In that regard, the government needs to prepare the necessary policies and rules for adapting the existing gas infrastructure to transport CO_2 and hydrogen, what may present a very cost-effective solution to support new clean technology developments.

Recommendations

The government of Denmark should:

- Maintain mini-rounds and neighbouring licensing rounds for existing offshore oil and gas fields with a view to potentially provide increased gas security for Europe in the near to medium term.
- Encourage electrification of offshore oil and gas production to reduce greenhouse gas emissions, including methane especially from Tyra, through timely provision of electric power interconnection while ensuring the costs of the interconnection(s) are borne by the oil and gas field operators.
- Accelerate the availability of compression services for new biogas plants to support their access to gas transmission networks.
- Swiftly evaluate and address the future uses of the existing gas pipeline system network amid declining Danish natural gas demand for the transport of both hydrogen and CO_2, comparing their operating and capital investment costs to alternative transport options, such as new dedicated pipelines.
- Invest in pre-feasibility work for hydrogen and CO_2 transport to define capacity and operating parameters, likely route, and right of way, and then use non-binding open seasons (in co-operation with neighbouring country pipeline operators as appropriate) to determine interest in the pipelines.
- If required, appoint an operator and design market-based capacity booking and transportation arrangements for hydrogen and CO_2 pipeline systems to minimise the financial risk to the state while mitigating the risks to hydrogen producers and CO_2 storage providers by setting the framework conditions (i.e. policy, including price of carbon, and regulatory, including permitting).

ANNEX A: Review team and supporting stakeholders

Review criteria

The Shared Goals, which were adopted by the International Energy Agency (IEA) Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the IEA's energy reviews.

Review team and preparation of the report

The energy review team visit took place from 30 January to 6 February 2023. The review team met with government officials, energy suppliers, market participants, public and private sector interest groups, consumer associations, research institutions, and other organisations and stakeholders.

The report was drafted on the basis of the information obtained during these meetings, the team's preliminary assessment of Denmark's energy policy, the Danish government's response to the IEA energy policy questionnaire, and information on subsequent policy developments from the government and private sector sources. The members of the team were:

IEA member countries

Ms Penelope Sirault, Australia (team leader)

Ms Isabel Teichmann, Germany

Mr Jan Hensmans, Belgium

Mr Bert Wilbrink, Netherlands

Mr Roland Gerber, Switzerland

Mr Scott Greenip, United States

Ms Julia Walschebauer, European Commission

International Energy Agency

Ms Sylvia Beyer, Senior Energy Policy Analyst and in-depth review co-ordinator

Mr Milosz Karpinski, Energy Security Analyst

The review team expresses its gratitude to Anders Hoffmann, Deputy Permanent Secretary and Chair of the IEA Governing Board; Lars Frelle-Petersen, Permanent Secretary; Henrik Kjærgaard, Deputy Permanent Secretary and Rune Pedersen, Head of Division, all from the Ministry of Climate, Energy and Utilities.

The team extends a special thanks to Lars Georg Jensen from the Danish Energy Agency and Sixten Rygner Holm and Marie Kehlet Hviid from the central Department of the Ministry for their tireless efforts in co-ordinating the review visit, prompt responses to the team's many requests, and patience throughout the weeks leading up to and during the review.

The entire review team extends its warm thanks to the teams for their effective management and co-ordination of the review, notably the peer expert visit, their tireless efforts and professional support at all times, and prompt responses to the requests throughout the review process.

Ms Sylvia Beyer and Mr Milosz Karpinski managed the review and the drafting of the final report. Ms Roberta Quadrelli and Ms Erica Robin from the Energy Data Centre led the energy data and statistics part of the review.

The following IEA staff provided insights and expert comments, chapter reviews and helpful updates: Ms Clara Camarasa, Mr Nicholas Howarth, Mr Cuauhtemoc Lopez-Bassols, Mr Pablo Hevia-Koch and Mr Gergely Molnar.

Special thanks to the IEA Secretariat with regard to the data, publication and editing. Mr Alessio Scanziani and Mr Anders Caratozzolo designed and prepared the energy data sections of the report, dedicated analysis, figures, tables and maps, supported by Ms Eléonore Carré, Mr Han Young Chang, Mr Ismail Aykin, Mr Eloi Borgne, Ms Stella Jun and Mr Edoardo Campo Lobato. Mr Alexandre Bizeul, Mr Pedro Carvalho and Mr Domenico Lattanzio provided support on statistics and data. Ms Isabelle Nonain-Semelin managed the editing process and Ms Astrid Dumond the production process. Ms Jennifer Allain edited the report. All maps were prepared by Ms Eléonore Carré.

Organisations visited

CIP

Concito

Confederation of Danish Industries

Danish Climate Council

Danish Competition and Consumer Authority

Danish District Heating Association

Danish Economic Councils

Danish Energy Agency

Danish Energy Association

Danish Utility Regulator

Danish Wind Industry Association

Danish 92 group

Dansk Offshore

Drivkraft Danmark

Energinet.dk

Europe Energy

Green Power Denmark

Ministry of Climate, Energy and Utilities

Ministry of Finance

Ministry of Higher Education and Science

Ministry of Taxation

Nature Energy

Nordsøfonden

Ørsted

SYNERGI

Technical University of Denmark

TotalEnergies

University of Copenhagen (Expert Group on Green Tax Reform)

University of Aalborg

ANNEX B: List of abbreviations

In this report, abbreviations and acronyms are substituted for a number of terms used within the International Energy Agency. While these terms generally have been written out on first mention, this glossary provides a quick and central reference for the abbreviations used.

Acronyms and abbreviations

AC	Alternating current
BOGA	Beyond Oil and Gas Alliance
CCS	carbon capture and storage
CCUS	carbon capture, utilisation and storage
COP	Conference of the Parties
CSO	Climate Status Outlook
DC	direct current
DCCC	Danish Council on Climate Change
DEA	Danish Energy Agency
DKK	Danish krone
DSA	Danish Subsoil Act
DSO	distribution system operator
DUC	Danish Underground Consortium
DUR	Danish Utility Regulator
EED	Energy Efficiency Directive
EPC	energy performance certificate
ETS	Emissions Trading System
EU	European Union
EUDP	Energy Technology Development and Demonstration Program
EUR	euro
EV	electric vehicle
FEC	final energy consumption
GDP	gross domestic product
GHG	greenhouse gas
IEA	International Energy Agency
IFD	Innovationsfonden
IPCC	Intergovernmental Panel on Climate Change
LPG	Liquefied petroleum gas
LULUCF	land-use, land use change and forestry
NECP	National Energy and Climate Plan
NEKST	National Energy Crisis Team
ODA	official development assistance

OECD	Organisation for Economic Co-operation and Development
PEC	primary energy consumption
PPP	purchasing power parity
PSO	public service obligation
PtX	Power-to-X
PV	photovoltaics
R&D	research and development
RD&D	research, development and demonstration
RD&I	research, innovation and development
SME	small and medium-sized enterprise
TES	total energy supply
TFEC	total final energy consumption
TRL	technology readiness level
TSO	transmission system operator
USD	United States dollar

Units of measurement

bcm	billion cubic metres
CO_2	carbon dioxide
CO_2-eq	carbon dioxide equivalent
g CO_2-eq	gramme of carbon dioxide equivalent
GJ	gigajoule
Gt CO_2	gigatonne of carbon dioxide
GW	gigawatt
kb/d	thousand barrels per day
kg CO_2-eq	kilogramme of carbon dioxide equivalent
kV	kilovolt
kW	kilowatt
kWh	kilowatt hour
L	litre
MJ	megajoule
Mt	million tonnes
Mt CO_2	million tonnes carbon dioxide
Mt CO_2-eq	million tonnes carbon dioxide equivalent
MW	megawatt
MWh	megawatt hour
PJ	petajoule
t CO_2	tonne of carbon dioxide
TWh	terawatt hour

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Government action plays a pivotal role in ensuring secure and sustainable energy transitions and combatting the climate crisis. Energy policy is critical not just for the energy sector but also for meeting environmental, economic and social goals. Governments need to respond to their country's specific needs, adapt to regional contexts and help address global challenges. In this context, the International Energy Agency (IEA) conducts Energy Policy Reviews to support governments in developing more impactful energy and climate policies.

This *Energy Policy Review* was prepared in partnership between the Government of Denmark and the IEA. It draws on the IEA's extensive knowledge and the inputs of expert peers from IEA member countries to assess Denmark's most pressing energy sector challenges and provide recommendations on how to address them, backed by international best practices. The report also highlights areas where Denmark's leadership can serve as an example in promoting secure clean energy transitions. It also promotes the exchange of best practices among countries to foster learning, build consensus and strengthen political will for a sustainable and affordable clean energy future.