Danish Energy Agency

Regulation and planning of district heating in Denmark

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An overview of district heating in Denmark and how the Danish district heating sector has been able to support Danish energy policy ambitions.

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Content

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1. Preface

As the Director General of the Danish Energy Agency, I am pleased to introduce this white paper on the regulation and planning of district heating in Denmark. This document provides a comprehensive overview of Denmark's journey with district heating, detailing its historical development and its pivotal role in supporting Denmark's energy policy ambitions. It examines the legal frameworks that have supported a thriving sector capable of delivering affordable and sustainable heating to households and businesses alike.

District heating is a cornerstone of Denmark's green transition. For more than 50 years, district heating has been an integral part of our energy system, evolving alongside Denmark's commitment to energy security, environmental sustainability, and carbon neutrality. It has been instrumental in enhancing energy efficiency, reducing our greenhouse gas emissions, and integrating renewable energy sources.

Through decades of innovation and collaboration, the Danish district heating system has grown from a localised solution into a robust and flexible infrastructure, creating a sustainable model that now inspires countries around the world.

The Danish experience emphasizes the importance of holistic planning, transparent regulation, and close cooperation between government, municipalities, and energy providers and consumers in creating a system that is both economically viable and climate friendly.

Denmark demonstrates that a commitment to green transition can yield remarkable results. Through solid regulation and long-term planning, we have achieved a high degree of efficiency and sustainability, contributing not only to Denmark's energy goals but also to our climate ambitions. Looking ahead, the role of district heating will become even more crucial as we transition toward a fully renewable and resilient energy system, with the integration of new technologies such as carbon capture, utilisation and storage and power-to-x.

We believe this white paper will serve as a valuable resource for policymakers, planners, and stakeholders around the world who are seeking inspiration for their own energy transitions. By sharing Denmark's experiences, we hope to foster dialogue, knowledge exchange, and collaboration that will help address the shared challenge of creating a sustainable and secure energy future.

On behalf of the Danish Energy Agency, I thank you for your interest in this report, and I invite you to explore the insights it contains. Together, we can accelerate the shift towards a greener, more sustainable global energy landscape.

Kristoffer Böttzauw

Director General of the Danish Energy Agency

2. Main characteristics of today's Danish district heating

As of 2024, around 69% of all Danish households were connected to district heating (DH) - not only for space heating, but also for domestic hot water. Denmark's six largest cities have central DH systems, while approximately 400 smaller DH systems scattered across the country. In 2023, the total DH production amounted to 38 TWh, covering 57% of the national residential heat demand.

In 2023, 62% of DH was produced through cogeneration with electricity (CHP[1]), significantly reducing fuel consumption compared to separate heat and power generation. CHP also enhances the energy system stability by helping regulate the power grid, with most of the electricity being generated by wind and solar in Denmark. Denmark's DH sector has also increasingly adopted renewable energy, now accounting for 78% of the DH production.

Heat supply

Heat supply options

Various technologies are used for heat supply in Denmark. While some consumers rely on individual heat supply such as oil boilers, gas boilers, biomass boilers, or heat pumps, the majority receive their heat from DH systems.

DH is primarily established in high-density urban and suburban areas, where heat demand is substantial. However, smaller towns and villages with around 500 households can also be supplied with DH.

To distribute DH within buildings, consumers must have water-based heating systems, such as radiators or floor heating. Lower temperatures in these systems allow for lower DH temperatures, improving efficiency. In Denmark, DH supply temperatures are relatively low, typically 80°C for supply and 40°C for return. DH companies encourage consumers to reduce the temperatures further to enhance efficiency.

Domestic hot water is typically produced using DH through instantaneous heat exchangers, though some systems also include hot water tanks to smooth out peak demand.

Production of district heating

DH is an efficient method to supply heat to multiple buildings from centralised sources, benefiting from economies of scale. DH systems can utilise a wide range of energy production technologies, including CHP plants, boilers, large heat pumps, large-scale solar heating panels, industrial surplus heat, and deep geothermal heat.

- Large-scale CHP plants

CHP plants are the largest contributors to DH production in Denmark, primarily using fuels such as waste, biomass, pipeline gas[2] and coal – though coal is being phased out, with the last coal-fired CHP plant scheduled to close in 2028.

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[1] A combined heat and power plant is an energy centre in which power is generated in a thermal process and the waste heat produced is provided as useful heat. This principle is known as combined heat and power (CHP) and the power is usually used to generate electricity.

[2] Pipeline gas: The mixture of natural gas and an increasing share of domestically produced biogas delivered through the existing gas grid.

CHP's high efficiency saves fuel consumption compared to separate heat and power production, assuming fossil fuel condensing plants remain on the margin.

Historically, large-scale CHP plants have been pivotal in enhancing energy efficiency, decoupling energy consumption from economic growth, and reducing carbon emissions over several decades by transitioning from fossil fuels to renewable energy. These plants supply heat to large distribution networks, often connected via heat transmission systems.

A notable example is the city of Aarhus, home to Denmark's second largest DH system in Denmark. Aarhus successfully transitioned from oil boilers to coal and waste-fueled CHP plants, later switching from coal to biomass-fueled CHP. Over time, CHP has been supplemented with an increasing proportion of electric boilers and large heat pumps, further supporting the green transition in a cost-effective way, benefiting both consumers and society.

CHP plants can adjust cogeneration based on electricity demand without compromising heat supply. Both large and smaller DH systems utilise short term heat storage, introducing flexibility to the energy system, which is crucial for optimising efficiency both economically and environmentally.

- A variety of medium-sized and small CHP-units and heat-only boilers

Smaller DH areas vary in size but typically consist of a single distribution network. Heat is produced by one base load unit and one or more peak and reserve units. The base load unit is typically a biomass CHP plant or a biomass boiler (e.g. straw or wood chips), while peak and reserve boilers are typically heat-only boilers fueled by oil, gas, or wood pellets, which have low investment costs. Today, several smaller DH areas supplement their systems with solar heating or electric boilers.

DH production in Denmark is increasingly shifting toward electrification, utilising heat pumps and electric boilers. The electricity market has played a key role in shaping this development, driven by lower and fluctuating electricity prices from wind and solar PV. Existing gas-fired CHP plants and boilers have been supplemented with large heat pumps, electric boilers, and expanded thermal energy storage.

Denmark's DH sector has undergone significant changes in recent decades, moving toward renewable energy and away from fossil fuels. This reflects Denmark's commitment to enhancing energy efficiency, increasing renewable energy use, and reducing carbon emissions – strengthening the flexibility and sustainability of the national energy system.

Fuels, heat sources, and electricity used for district heating

The fuels and heat sources used for heat production plants, including both CHP plants and heat-only plants, consist of both fossil fuels (coal, oil, natural gas, and non-biodegradable waste) and non-fossil sources (biomass, biodegradable waste, biogas/biomethane, geothermal heat, solar thermal, biooil, surplus heat and heat recovered via heat pumps). Two thirds of the electricity used in heat pumps and electric boilers can be regarded as renewable from primary wind and solar PV, whereas the remaining third comes from a mix of biomass, waste incineration and fossil fuels.

Figure 1 provides an overview of the development of these energy sources for DH since the 1970s. The figure shows that the usage of renewable sources has increased significantly since the late 1980s and reach now 78% in 2023.

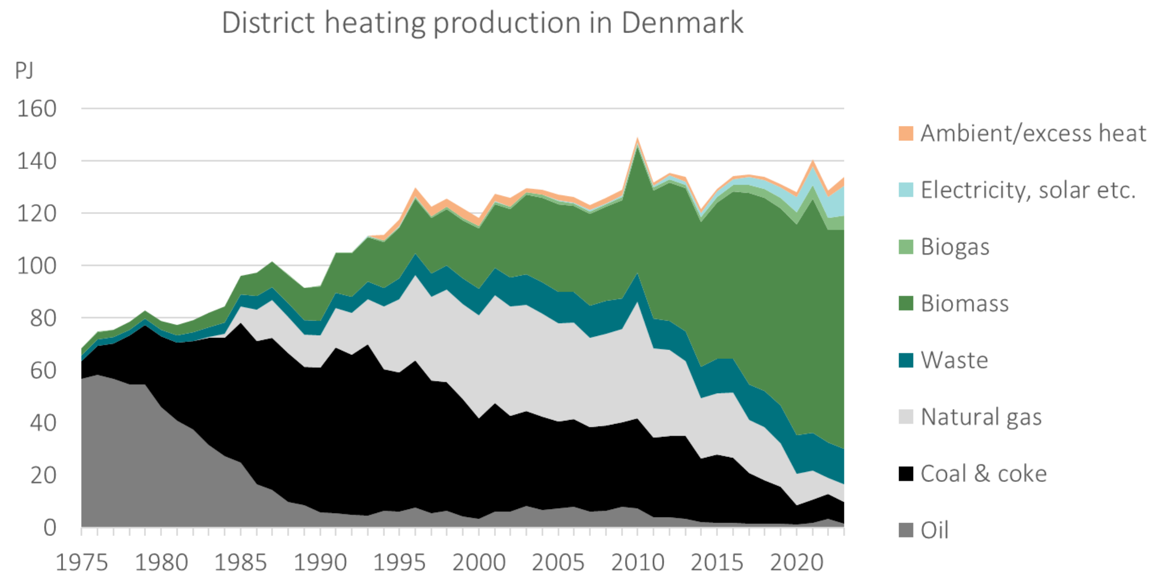

Figure 1 – Share of fuels, heat sources, and electricity used in production of DH. Ref.: DEA Energy Statistics 2023

Biomass

Biomass has been a key fuel source in Denmark's DH sector for decades. The 1970s energy crisis prompted a shift from imported oil to natural gas and renewable energy, including biomass. By 2023, biomass use for DH production (excluding biodegradable waste-to-energy) reached 66.5 PJ, compared to 7 PJ in 1990. The increase in sustainable and thereby renewable biomass comes from an increase in domestic biomass combined with an increase in the net import. Figure 1 shows that in 2023, the share of biomass in the DH production has reached 62%.

Denmark's goal to phase out fossil fuels has made biomass an essential transition fuel, but its role is expected to decrease as DH systems shift towards electrification and other renewables.

Waste to Energy

Waste makes up an important energy resource for DH production in Denmark, representing almost 20% of the fuel sources for heat production, see Figure 1. Almost all non-recycled waste is converted into energy, with only a small fraction (1-2%) being sent to landfills.

Waste-to-energy is one of the cornerstones of Danish waste management, producing both heat and power in highly efficient CHP plants. Fossil-based waste, particularly plastics, is gradually being phased out to reduce the environmental impact, as most of the plastics are recycled.

Solar heating

By the end of 2022, over 100 large solar DH plants, with a total collector area of over 1.3 million square meters are operating across Denmark, which represent a total installed capacity of over 1 GW. Denmark is the leading country in both solar district heating capacity and numbers of solar district heating plants around the world.

Before 2005, there were few solar heating plants in Danish DH systems. However, the technological development in solar heating combined with a change in regulatory setup for small-scale CHP plants, started a development of solar heating specifically for DH production.

These solar heating plants, primarily used for summer load, can store excess heat in seasonal thermal storage for use in colder months. Currently, there are five huge seasonal heat storages of the pit thermal energy storage type in Denmark that operate together with large solar heating systems. The largest pit storage is more than 200,000 m^3, which operates together with a solar heating plant of 70,000 m^2 solar collector area in the DH system of Vojens.

Since 2017, however, solar heating installations have stalled due to increased electrification, with technologies such as heat pumps and electric boilers offering more efficient and cost-effective solutions.

Structure of the DH sector

Natural monopoly of DH networks versus competitive heat production

DH networks function as natural monopolies as there is only one DH supplier in a given area, making it more efficient and cost-effective than having parallel DH suppliers.

While the networks are monopolies, heat production is more likely to be subject to competition. Various producers, e.g. CHP, waste heat recovery, and renewable energy sources, can supply heat at different prices based on different conditions and circumstances. DH operators optimise heat supply from the cheapest available sources, fostering competition among heat producers.

Ownership and sector organisation

As shown in Figure 2, DH companies in Denmark are mostly owned by the customers, either directly as cooperatives or indirectly through municipal ownership, representing a model of local democratic ownership.

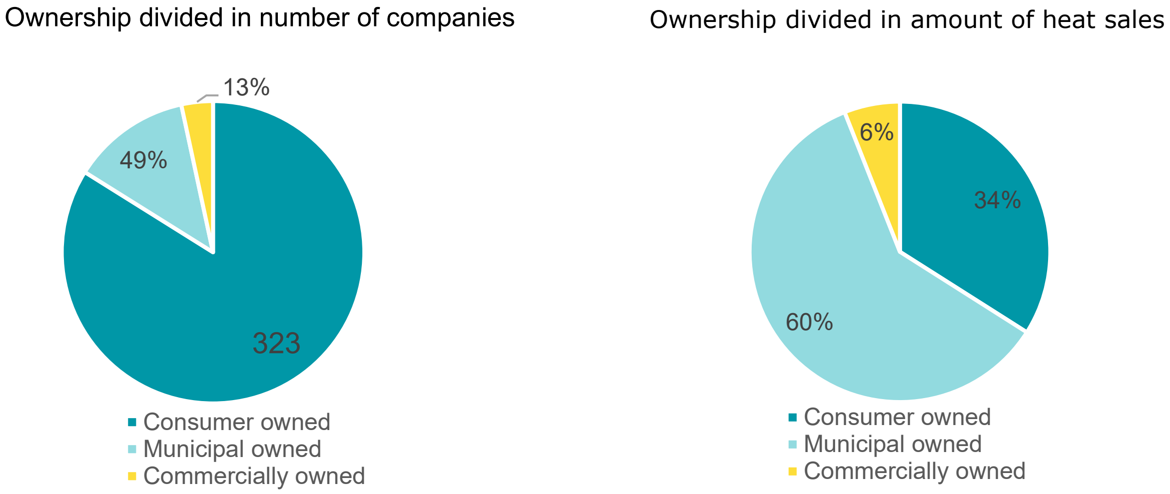

Figure 2 – Share of consumer owned, municipal owned and commercial owned DH companies in Denmark in 2020. Ref. Annual Statistics 2020 by Danish District Heating Association

Nearly all DH supply (99.9%) is provided by DH companies organised under the private Danish District Heating Association (Dansk Fjernvarme). These companies also provide about 40% of Denmark's thermal power generation.

Consumer controlled supply

A common feature of all DH areas in Denmark is that heat supply is controlled by the consumers' heat demand. Consumer metering measures the actual heat demand, incentivising consumers to save heat, as part of their heat bill is based on heat consumption.

Cost and pricing

Heat price – the principle of necessary costs

Danish law requires that DH prices as a general rule only cover necessary expenses related to heat supply, as DH network companies operate on a non-profit basis. Each DH network company sets its own tariffs based on local conditions.

The tariffs are usually structured in two parts:

- Fixed part (per installation and/or capacity or heated area) covering financial costs (system depreciation and loan interest), administration and maintenance
- Variable part (per MWh of consumption) based on heat production costs, which depend on factors such as heat purchase costs, fuel prices, electricity prices, network efficiency and taxes.

Usually in Denmark, approximately two-thirds of the heating bill is variable and dependent on heat consumption. This reflects the fact that in general, energy costs, including taxes, make up the largest proportion of total costs.

Heat price and economies of scale

Heat prices tend to be be lower in large-scale DH systems due to economies of scale and higher heat density, leading to lower capital costs and reduced heat losses. Larger plants also benefit from bulk purchasing fuel or electricity at lower prices.

As a result, DH is in many cases more affordable for consumers compared to individual heating solutions, making it a key driver for expanding DH systems in Denmark.

Investment costs and operating costs

Establishing DH systems requires significant upfront investments in production facilities and distribution networks. These costs are shared among all connected consumers, distributing the financial burden.

While individual solutions, such as a heat pumps, may have lower initial costs, DH systems have a longer technical lifetime, allowing the initial investment to be spread over a longer period of time.

Operating costs in DH systems are often lower compared to individual gas and oil boilers, especially when using efficient heat pumps, CHP plants or waste heat recovery. However, in some cases, individual heat pumps can be competitive.

The life-cycle viewpoint

When evaluating DH systems, lifecycle costs or levelized costs of energy (LCOE) indicate that DH is often the most cost-effective solution in the long term. Infrastructure investments are recovered through lower annual costs, and high-quality components, whilst more expensive initially, reduce maintenance expenses, resulting in lower overall costs for both operators and consumers.

It is important to consider that the technical lifetime of a high-quality DH network is typically 40–50 years, while the technical lifetime of an individual heat pump is around 16 years.

3. The history of Danish district heating

The first CHP plant in Denmark was built in 1903. It was a waste incineration plant, designed to manage waste while providing electricity and heating to a nearby hospital. Since then, significant developments have taken place. The oil crisis in 1973 kickstarted Danish energy policy, leading to the adoption of Denmark's first Heat Supply Act in 1979. This legislation established DH, primarily based on CHP and waste to energy, as a key component in developing of a cost effective, environmentally friendly, and resilient energy sector.

Early development

During the 1920s and 1930s, municipal utilities in Denmark began developing DH systems based on waste heat from local electricity generation. In the 1960s, citizens in many Danish cities formed cooperatives to establish DH systems. These systems were often based on centralized heavy oil boilers.

Since then, DH areas have expanded significantly, with increased production diversity and a shift toward greener energy sources.

Figure 3 illustrates the growth in total heated floor area connected to DH, which has increased significantly in recent decades to more than 55% today[3].

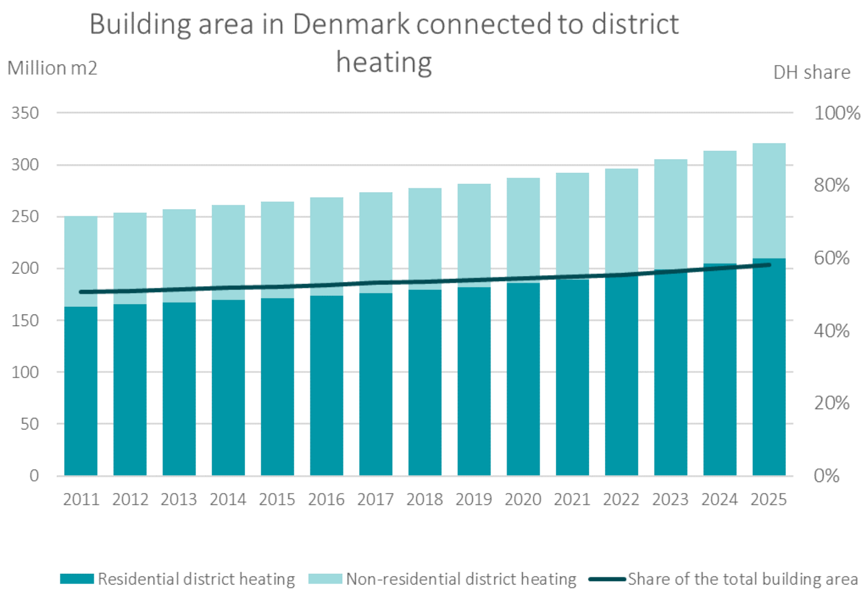

Figure 3 – Building areas in Denmark connected to DH. Ref.: Statistics Denmark

[3] According to Statistics Denmark: In 2024, 68.4% of homes in Denmark have DH (Table BOL102) and 61.2% of the residential floor area in Denmark has DH (Table BYGB40).

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Figure 4 shows the development of total net heat demand and the share of DH since the 1970s. The modest growth in heat demand for DH is largely due to energy-saving measures in buildings and reduced heat losses.

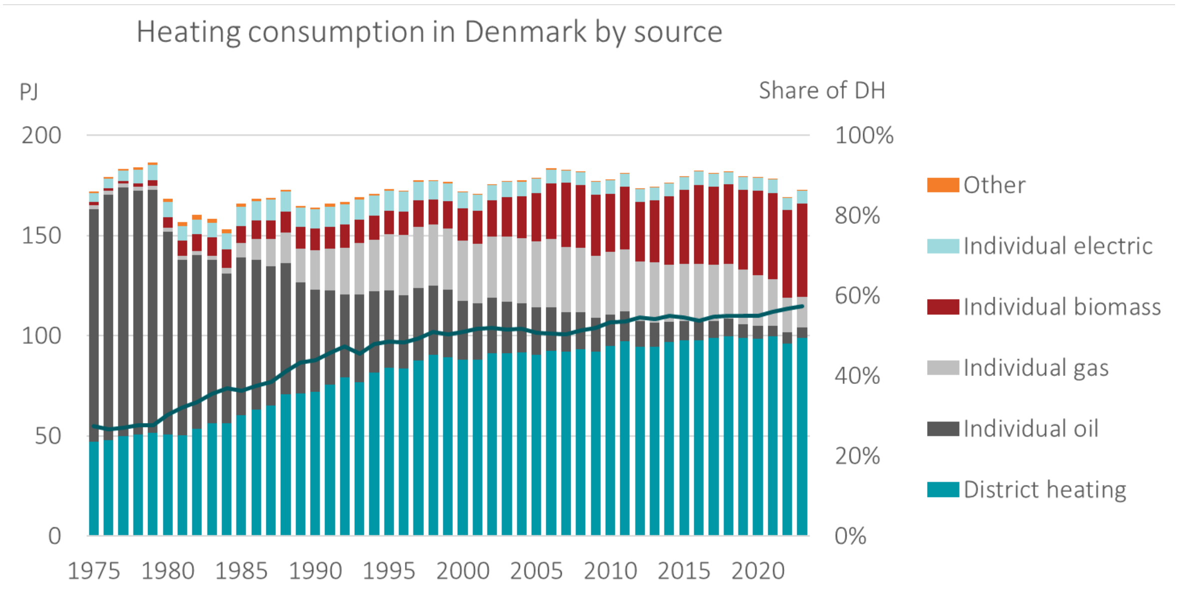

Figure 4 - Net heat demand by source. Ref.: DEA Energy Statistics 2023

Impact of the 1973/74 energy crisis

At the time of the energy crisis in 1973/74, energy consumption per capita had risen considerably. In response, CHP plants became a central national strategy for improving energy efficiency and reducing dependency on imported fossil fuels.

As a result, DH from CHP began to expand significantly in larger Danish cities in the late 1970s and in the 1980s. From the early 1990s onwards, this expansion extended to small- and medium-sized cities as well.

Figure 5 illustrates the development of DH production in Denmark by type of production plant since the 1970s. The largest contribution comes from CHP plants, both centralised and decentralised.

CHP production peaked around the year 2000 but has since declined slightly due to the growing share of wind and solar PV energy in the electricity market, and to a smaller extent the introduction of other efficient heat sources, such as solar heating panels and heat pumps.

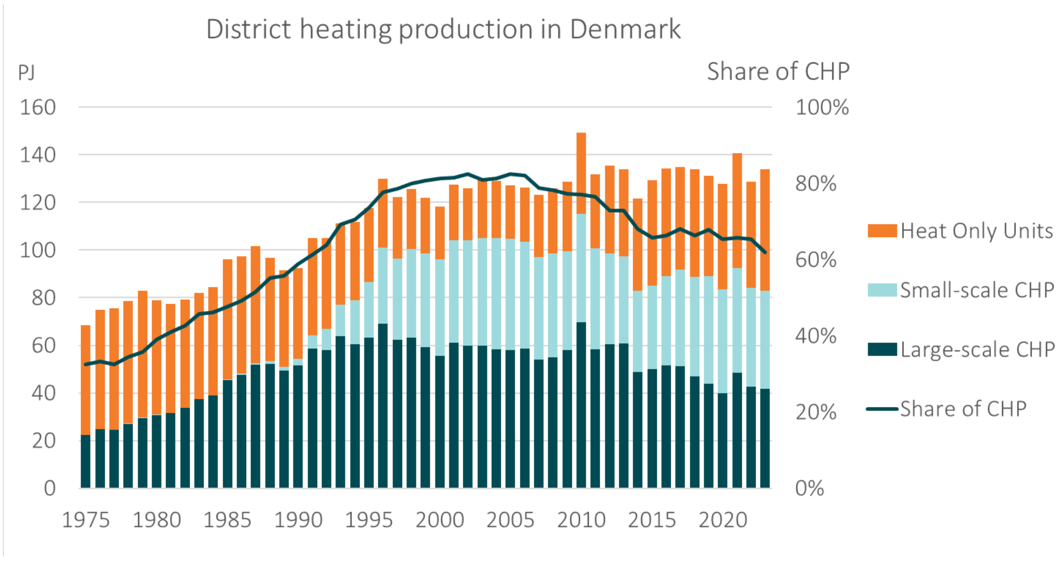

Figure 5 - DH production in Denmark by type of production plant. Ref.: DEA Energy Statistics 2023

First Heat Supply Act (1979)

Denmark was greatly affected by the international oil crises. By the end of the 1970s, this led to the formulation of a new energy policy aimed at enhancing security of supply and reducing dependency on oil.

To achieve these policy goals, while also utilising the natural gas resources recently discovered in the Danish part of the North Sea, Denmark passed its first Heat Supply Act in 1979. Together with the Electricity Supply Act (1976) and the Gas Supply Act (1979), the Heat Supply Act established the regulatory groundwork for the expansion of gas-fueled CHP in Denmark, along with other types of CHP.

The Heat Supply Act introduced regulations regarding the form and content of heat planning in Denmark, marking the beginning of a new era in public heat supply planning, which continues to this day.

Zoning of DH and gas areas

Within the framework of regional plans, and following negotiations with local energy utilities, local authorities prepared municipal heat plans. These heat plans included zoning, which defined the areas designated for DH or natural gas supply.

The purpose of zoning was to establish cost-effective, low-emission energy systems in urban areas. Zoning also prevented overlapping infrastructure and avoided overinvestment by identifying the most viable areas for DH or gas network development.

Approval of heat supply projects based on costs

Projects involving the establishment, expansion, or other changes of local DH systems (both network and production) or local natural gas networks are subject to local authority approval and must align with regional and municipal heat plans.

The Heat Supply Act stipulates that the approval of heat supply projects must be based on a socioeconomic analysis, in accordance with guidelines issued by the Ministry of Finance and the Danish Energy Agency (DEA). These guidelines consider factors such as energy prices, emission costs, and discount rates.

This principle remains in use today. To assist DH and gas network companies and local authorities in conducting the relevant economic analyses, the first Danish technology catalogue was developed in 2016. The DEA also publishes guidance documents for socioeconomic calculations and project approvals. These resources provide information, not only on heat supply plants, but also on other items of importance, such as how to calculate the distribution of heat demand over the year, how to assess the investments in gas networks and DH networks etc. This standardized approach ensures consistent and comparable evaluation of heat supply options across Denmark.

Cogeneration of heat and power

Since the Electricity Supply Act was passed in 1976, all new power plants have been designed as CHP plants. This approach has nearly eliminated waste heat, which was previously lost through seawater cooling during electricity production.

Additionally, the new large-scale CHP plants were strategically located in urban areas to maximize societal benefits by utilising recovered heat for DH.

The subsequent Heat Supply Act (1979) further accelerated the expansion of efficient DH systems based on CHP plants, facilitating the transition from oil to coal and gas.

Possible mandatory connection and ban on electric heating

The Heat Supply Act granted municipalities the authority to require new and existing buildings to connect to the public DH or gas network, provided it was cost-effective for society. This measure helped ensure positive project economics for consumers and mitigated financial risks associated with large-scale investments, which were typically financed through municipal-guaranteed loans.

From a societal perspective, mandatory connections, along with the zoning regulations, prevented competing heat supply infrastructures from imposing financial burdens on one another within the same urban areas.

However, over time, obligatory connection was increasingly viewed as restrictive, limiting consumer choice and hindering the development of a more dynamic and competitive energy market. As a result, the option to enforce obligatory connection in new projects was removed in 2019, though it still applies to DH projects approved before the law change.

Tax incentives for efficient use of energy

During the 1980s, taxes were applied to fossil fuels used for heat generation to encourage the use of environmentally friendly energy and promote efficient energy utilisation. Therefore, biomass and biogas were exempted from taxes.

When oil and gas prices dropped at the end of the 1980s, the tax level for these fuels was increased. However, only the additional fuel consumption for generation of heat at CHP plants was taxed. This ensured that consumers and DH companies remained motivated to use environmentally friendly energy sources and reduce energy consumption.

Focus on environment and expansion of cogeneration in the 1990s

Phased conversion from heat-only boilers to CHP

With an amendment to the Heat Supply Act in 1990, a new planning system was introduced. A "project system" was developed based on a general framework set out in a political agreement. The objective was to promote expansion of decentralised CHP through:

- Conversion of existing installations to co-generated heat and electricity supply
- Increased use of natural gas
- Increased use of environmentally friendly fuels
- Growth of energy production from CHP plants

The agreement aimed to address two key issues, namely reducing Denmark's CO_2-emissions and ensuring the economic viability of expanding the natural gas network through increased sales of natural gas.

The transition from heat-only boilers to CHP, as formulated in the agreement, took place in three phases:

1. Phase 1 (1990-1994)
    - Large coal-fired DH units with access to natural gas supply were converted to gas-fired CHP.
    - Larger natural gas-fired DH units were converted to CHP.
    - Relevant waste incineration plants were considered for conversion to CHP.
2. Phase 2 (1994-1996)
    - Remaining coal-fired DH units with access to natural gas supply were converted to gas-fired CHP.
    - Medium-sized natural gas-fired DH units were converted to CHP.
    - DH units without access to natural gas were required to consider conversion to straw, wood chips, or other biofuels.
3. Phase 3
    - Smaller natural gas-fired DH units were required to convert to CHP.
    - Remaining DH units without access to natural gas were required to consider conversion to straw, wood chips or other biofuels.

As a result of these initiatives, combined with attractive policy incentives, Denmark today has one of the highest shares of cogeneration of heat and power in Europe.

Renewables in heat supply

Renewable energy for heat supply became a priority in the 1990s, when targets were set for the increased use of biomass at both centralised and small-scale plants.

The use of biomass was supported by policy measures and financial subsidies. In particular, the Biomass Agreement (1993) facilitated biomass adoption in centralised plants. This agreement required power plants to use 1.2 million tons of straw and 0.2 million tons of wood chips annually by the end of 2000. Later, the agreement was altered to allow a more flexible choice of biomass.

In 1987, a biogas action plan was introduced to develop competitive biogas plants. By 1995, it was concluded that biogas technology had advanced sufficiently to play a role in Denmark's energy supply. Today, biogas is used either directly for CHP production or upgraded to biomethane and mixed with natural gas in the national gas network.

In recent years, Denmark has strengthened support for solar heating, heat pumps, and geothermal energy to accelerate the transition to renewable energy in the heating sector. Key measures include lowering the electricity tax on heating to make heat pumps more competitive and expanding subsidies for DH networks to replace fossil fuel-based heating. This is further encouraged by the commitment to phase out coal-based electricity production by 2030, with the last remaining coal-fired CHP plant scheduled to be decommissioned in 2028.

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4. Regulation of the district heating sector

The Heat Supply Act is the central law governing the planning, development, and regulation of the heating sector in Denmark. Originally adopted int 1979 and subsequently revised multiple times, the Heat Supply Act aims to promote the most cost-effective and environmentally friendly use of energy for heating buildings and producing hot tap water. Within this framework, the act also seeks to reduce dependency on fossil fuels. Thus, it plays a decisive role in Denmark's efforts to promote cost-effective and resilient heat supply solutions, reduce greenhouse gas emissions and ensure a reliable and affordable heat supply for citizens.

Key players and regulations in the Danish DH sector

The Danish Ministry of Climate, Energy, and Utilities plays a vital role in shaping and implementing Denmark's energy and climate policies. It also regulates utilities in key sectors, including district heating and cooling, electricity, and gas.

The Danish Energy Agency (DEA), operating under the Ministry, is responsible for developing, planning, and executing national energy policies. It provides crucial support to the energy sector, including DH, through research, data collection, and analysis.

The Danish Utility Regulator (DUR), along with the Energy Appeal Board, oversees the DH sector and addresses complaints related to prices and conditions. Appeals against public authority decisions or interpretations of laws and regulations can be directed to the Energy Appeal Board.

Municipalities play a central role in Denmark's collective heat supply. Their responsibilities include heat planning, approving projects for collective heat supply, and ensuring that DH expansion and system changes are in line with the Heat Supply Act.

DH network companies operate under the non-profit principle, meaning that the price charged for DH must be set at a level that only covers necessary expenses for production, operation, and maintenance. This principle ensures that DH network companies cannot generate profits from their operations. Any surplus income must either be returned to consumers through lower tariffs or reinvested into the DH system according to specific rules.

Authorities overseeing the DH sector and handling complaints

THE DANISH UTILITY REGULATOR (DUR) oversees heat prices in the DH sector and handles complaints related to heat pricing and delivery conditions. All DH companies, including network and production units, are required to submit information to DUR on prices and conditions. This allows the regulator to monitor the sector and address complaints and objections effectively.

THE ENERGY APPEAL BOARD handles complaints related to DUR’s decisions in individual cases, as well as any possible misinterpretation of the law. Appeals can be made regarding decisions by the Danish Ministry of Climate Energy, and Utilities, the Danish Energy Agency, the Danish Utility Regulator, and the municipalities.

The Heat Supply Act and municipal heat planning

The Heat Supply Act is the cornerstone of Danish heat supply regulation. It regulates public heat supply installations, including DH systems. Under the act, municipalities are tasked with developing and updating municipal heat planning, which must be carried out in cooperation with utility companies and other key stakeholders. The overall objectives of heat supply planning are to promote the most cost-effective form of heat supply for society, including environmental costs, reduce dependency on fossil fuels, promote cogeneration of heat and electricity, and support the use of renewable energy sources.

Municipalities also evaluate and approve projects proposed by DH companies in accordance with the act's provisions. These projects may include the expansion of DH networks, new supply areas, installation of heat supply plants with a thermal output of at least 0.25 MW, and CHP plants with an electric output of up to 25 MW.

The need for a project proposal

When a DH unit or network is established, or a major change is made to an existing system (such as a change of fuel, technical concept, or expansion of a production unit), a project proposal must be prepared and submitted to the municipality for approval by the city council. For research projects and similar initiatives, it is possible to apply for a dispensation from legislative requirements.

A project proposal must comply with specific policies and rules, including various requirements, e.g., the choice of fuels. The project proposal must include socio-economic, user-economic, and company-financial analyses. These analyses must compare relevant project alternatives against a realistic baseline. The city council can only approve the project proposal if it offers the greatest socio-economic benefits, including environmental costs.

To support the preparation and evaluation of project proposals, the DEA provides guidelines for socio-economic analysis and datasets with assumptions. These assumptions include, among others, forecasts for fuel and electricity prices, externality costs for emissions and interest rates. The DEA also provides a technology catalogue with data on various technologies, which can be used when more accurate data is not available.

Before a project can be implemented, additional various approvals and permits may be required, depending on the nature of the project. For example, the applicant shall submit an initial environmental impact assessment, which the competent authority (usually the municipality) screens to determine whether a full environmental impact assessment is necessary. Typically, DH projects do not require full assessment but must comply with agreed environmental protection measures.

Socio-economic cost-benefit analysis for evaluation of heat supply projects

In Denmark, the primary approval criterion for heat supply projects is the socio-economic cost-benefit analysis, ensuring that only projects delivering the greatest net benefit to society are prioritised.

This type of analysis accounts for all societal and external costs related to heat supply projects. It always involves a comparison of two or more alternatives, where taxes and subsidies are excluded, and externalities, such as emission costs, are incorporated. Each project alternative, including the proposed project, is assessed over its entire expected technical lifetime. If the technical lifetimes of different technologies vary, the analysis includes scrap values or reinvestment costs to maintain an accurate evaluation.

The socio-economic analysis must follow a standardized methodology based on data provided by the DEA. This dataset includes forecasts of future energy prices, cost estimates for emitting pollutants, and other economic and environmental considerations essential for a comprehensive assessment. This standardisation ensures that heat supply projects are evaluated using a consistent methodology, allowing for fair comparisons across different proposals.

The DEA is also responsible for maintaining a national technology catalogue, containing data on costs and technical specifications of various heat production units and DH distribution systems. This resource helps municipalities and DH companies develop accurate cost estimates, strengthening the planning and approval process. However, if a DH company applying for project approval possesses more precise local data, it may use its own figures instead of those provided by the DEA.

Non-profit principle

Public heat supply in Denmark operates under non-profit rules and regulations, based on two key principles from municipal law:

- Supply services must not result in indirect taxation of consumers. In other words, municipalities cannot increase their income through utility services.
- Supply services must not result in an indirect subsidisation of consumers. In other words, municipalities cannot provide subsidies to utility service users.

The Heat Supply Act defines which expenses can be included in heat pricing. Only these "necessary expenses" may be factored into the final cost to consumers.

DH companies are obliged to:

4. Prepare an annual budget and tariff that balance costs and revenues
5. Submit their budget and tariff to the DUR, which publishes the tariff in annual statistics
6. Provide cost documentation upon request

At the end of the year, any profit or deficit must be transferred to the next year's budget, or the final payment by the consumers must be adjusted. This regulation ensures that heat prices remain low for consumers and prevents DH companies from accumulating profit, aligning with the ownership structure.

Figure 6 illustrates how Danish DH companies' costs were divided among production, distribution, and administration in 2020. As shown, 95% of costs were attributed to heat production and distribution.

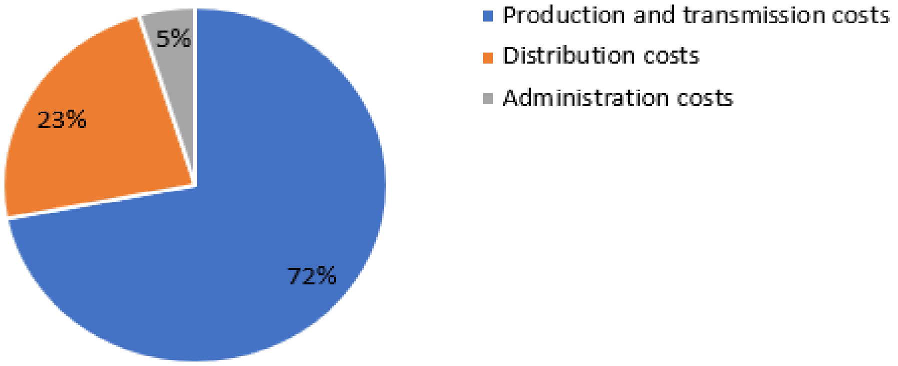


Figure 6 - Danish DH companies' costs divided by production and transmission, distribution, and administration. Ref. Annual Statistics 2020 by Danish Heating Association

Third party producers supplying renewable energy or surplus heat from the industry and business sectors to DH systems can generate profits within current regulations. These producers are not subject to the non-profit principle, if they sell heat based on renewable energy to a DH company. However, the DUR can cut profits if they determine that the costs are not 'necessary costs' or result in unreasonable consumer prices.

Return on investment, depreciation and provisions for new investments

Certain costs may be included as necessary costs, including:

- Depreciation, with repayment periods ranging from 5 to 30 years (except for network investments, where the maximum repayment period is 45 years)
- Provisions for new investments, which can be included up to 5 years before the investment is operational

Reasonable (low) return on invested capital, which must be by the DUR through a specific application..

Consumer protection

The principle of necessary costs and reasonable prices is designed to protect the consumers from potential abuse of the DH natural monopoly by ensuring that DH prices remain cost-based. DH companies cannot charge consumers beyond necessary expenses or generate profits.

However, the principle of necessary costs, reasonable prices and non-profit alone does not guarantee protection against inefficient management or operation. In this context, consumer or municipal ownership of DH companies helps provide oversight and accountability, mitigating inefficiencies. Nevertheless, DH prices in some areas are considered high, prompting regulatory adjustments to strengthen consumer protection:

- An indicative price cap on DH consumer prices was introduced in 2025.
- Municipal DH companies must maintain a clear separation between authority and operation.
- DH company boards must include at least two independent board members.

- Authorities are considering regulatory flexibility to increase efficiency in DH companies.

Energy sources

An amendment to the Heat Supply Act in 2021 removed the previous requirement to use natural gas in new DH projects within natural gas-supplied DH areas. However, existing bans on new coal-fired plants with an electricity capacity under 25 MW and mineral oil use for base load were maintained. Moreover, city councils were granted the authority to disregard fossil fuel scenarios in their approval of DH projects, including in socio-economic analyses.

This legislative change facilitates the transition to sustainable energy sources, while compliance with other relevant legislation, including environmental regulations, remains.

Sharing costs and income between heating and electricity

A key challenge in monopoly regulation is preventing cross-subsidisation between regulated monopoly activities and commercial activities. This is particularly relevant for DH, which through e.g. CHP is closely connected with the liberalised electricity sector.

In a CHP context, cross-subsidisation from the regulated heat supply to the liberalised electricity supply occurs when heat prices are higher than they would be without CHP generation, and electricity is sold below the marginal cost of production. Within this definition, there are still several possibilities for sharing costs and income between the electricity and heating sides.

Today, the sharing of costs at large CHP plants, which are allowed to make profit in the electricity market, is based on negotiations between the electricity and heating side. For small-scale CHP units, it is allowed that heat production costs are simply determined as “net heat production costs”, factoring in total electricity sales revenue. In other words, at small-scale CHP units, the possible total profit from electricity sales can reduce the heat price for the consumers.

Subsidies and taxes

Subsidies supporting the green transition

Denmark continues to provide subsidies for CHP plants, though many older schemes, especially those supporting fossil-fuel based plants have been phased out as part of Denmark's transition to renewable energy. However, specific support mechanisms remain for CHP plants utilising renewable energy sources, contributing to the country's green transition.

Current support mechanisms include:

- Some biomass-based CHP plants remain eligible for subsidies, though these have been gradually reduced to encourage a more diverse mix of renewable energy technologies.
- CHP plants using biogas may qualify for support under Denmark's renewable energy incentive schemes. These can take the form of feed-in tariffs or premium payments for renewable electricity generation.
- Broader schemes aimed at the heat supply sector, such as the district heating fund and the heat pump subsidy scheme, offer financial support or grants for converting to renewable fuels or improving energy efficiency.
- In some cases, building renovation grants (Bygningspuljen) and tax deductions for energy renovations (håndværkerfradraget) may also indirectly support the transition to renewable heat sources and improved energy efficiency.

Taxes on fuels used for heat production

Denmark imposes taxes on the use of fossil fuels for heat production, while biomass and other renewable energies are exempt. Therefore, Danish DH producers have an incentive to use biomass fuels instead of fossil fuels. For electricity used for heating, taxes are reduced to the EU minimum, making them nearly equivalent to those applied to non-fossil fuels.

Taxes apply to fuels and electricity used for heat production, but taxation for fuels used in electricity production differs. Instead of taxing the fuel type directly, Denmark levies taxes on the consumers' use of electricity. Since fuels used for electricity production are not directly taxed (except for VAT), CHP plants must allocate fuel consumption between heat and electricity production.

For tax purposes, a fiscal heat production efficiency of 120% is often applied. For example, if a CHP plant produces 1 MWh of heat in cogeneration with 0.65 MWh of electricity, the fuel consumption allocated to heat production is calculated as (1 / 120%) MWh = 0.83 MWh. The remaining fuel consumption is allocated to electricity production.

In addition, Denmark is implementing a green tax reform, introducing a high and uniform carbon tax across sectors. This aims to strengthen economic incentives for reducing greenhouse gas emissions and accelerating the implementation of climate-friendly technologies.

As part of this effort, Denmark has voluntarily chosen to include waste incineration plants in the EU Emissions Trading System (ETS). As a result, these facilities are now subject to CO_2 quotas, alongside other energy-producing installations within the EU.

Recent energy policy agreements

Since Denmark's first national energy strategy in 1976, numerous energy policy agreements have shaped the country's energy landscape, all backed by a solid parliamentary majority. Below is an overview of recent agreements that influenced DH planning in Denmark.

Energy Agreement 2018

The Energy Agreement 2018, modernized the Danish Heat Supply Act, granting greater flexibility to DH companies and consumers. This reform expanded opportunities for DH companies to invest in greener energy solutions, such as heat pumps, biomass, and geothermal systems, enabling the transition to renewable energy. Additionally, the agreement ensured that consumers have greater freedom to select their heat supply solutions. Municipalities can no longer mandate DH connections in newly established DH areas, allowing homeowners to explore alternative individual heat supply solutions, such as heat pumps for single-family homes.

Climate Agreement for Energy and Industry 2020

This agreement introduced several key measures impacting the Danish DH sector, which include:

- Promotion of electrification of DH. The agreement encourages the integration of renewable energy sources, such as wind and solar PV, and the use of heat pumps. With further reduction on the electricity-to-heat tax and increased tax on fossil fuels for heating, it favours electrification and green energy adoption.
- Phasing out oil and natural gas in the heating sector. This is being done through schemes to support the transition to individual heat pumps and DH, while removing regulatory barriers for converting natural gas-based heating to DH.
- Promotion of the utilisation of surplus heat. The agreement reaffirmed previous agreements promoting the use of surplus heat from industrial processes. Additionally, the framework conditions for geothermal heat was reviewed, and sustainability requirements for wood biomass were introduced.

Climate agreement on green electricity and heat 2022

This agreement set a political ambition to eliminate natural gas for space heating by 2035. To achieve this goal, Denmark is accelerating DH expansion and promoting the adoption of individual heat pumps.

EU's Energy Efficiency Directive (EED)

The EED plays a central role in shaping the future of DH in Denmark, reinforcing the country's commitment to energy efficiency. It establishes 'Energy Efficiency First' as a fundamental principle in EU energy policy, prioritising cost-effective energy efficiency measures to reduce energy consumption, thus reducing environmental impacts, lowering costs, and supporting the transition to a low-carbon economy.

The principle gained prominence with the European Green Deal and the “Fit for 55” package in 2021, supporting the EU's 2030 energy efficiency targets its goal of climate neutrality by 2050.

For DH, the EED and 'Energy Efficiency First' principle promote CHP systems, integration of renewable energy and utilisation of surplus heat from industrial processes and other sources. By aligning with the EED, Denmark can strengthen its leadership in efficient DH and contribute to both national and EU-wide energy and climate goals.

5. Future development trends for district heating in Denmark

Denmark's energy policy motivations have evolved over time, and DH systems have demonstrated their flexibility to develop and continuously support various political goals. Looking ahead, DH will remain a key contributor in achieving both short- and medium-term energy and climate targets, particularly the EU's 2030 climate goals, as well as the long-term ambitions up to 2050.

Denmark's climate and energy ambitions

Denmark is at the forefront of EU's climate ambitions, aiming to cut net greenhouse gas emissions by 55% by 2030, per the EU's "Fit for 55" plan. Denmark's 2020 Climate Act sets an even more ambitious 70% reduction target by 2030.

In 2023, Denmark generated 63% of its electricity from wind and solar, with renewables covering 44% of total energy consumption. This progress is expected to lower emissions by 55% by 2025, exceeding the 50-54% target.

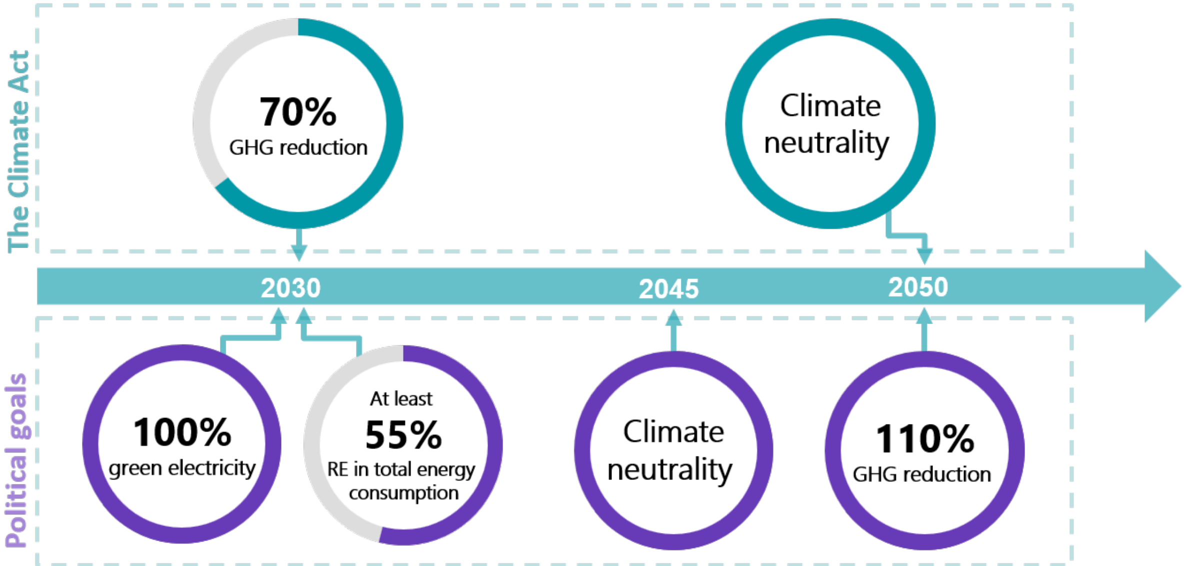


Figure 7 - Denmark's energy and climate political goals and targets set by the Climate Act

The EU aims for climate neutrality by 2050, while Denmark has set its own political net-zero goal for 2045, as shown in Figure 7. DH will play a pivotal role in meeting these targets, helping to balance fluctuating renewable energy supplies. As electrification spreads across sectors, flexible DH systems will be crucial for integrating wind and solar energy, further supporting Denmark's long-term renewable energy goals.

Danish Climate Status and Projections: A Vision of Integrated Sectors (2024)

The Danish Climate Status and Projections 2024 report (KF24 report) highlights Denmark's continued progress towards a greener future, with DH as a core pillar of this transition:

- As Denmark moves toward a fossil-free energy supply, the DH sector must adapt. Lower energy demand from improved insulation and increased wind and solar PV integration reshaping heat production, especially in CHP plants. These plants will continue to play a crucial role in balancing the electric grid in the future.
- The report predicts a growing reliance on heat pumps and electric boilers powered by renewable energy, especially wind and solar PV. In addition, DH will integrate more industrial surplus heat and solar heat, while biomass-based heat production is expected to decline. This shift toward sector integration ensures an optimal balance between resource availability and the high penetration of wind and solar energy.
- Although total heat demand is expected to decrease toward 2050 due to more energy-efficient buildings, DH coverage will remain robust. The focus will continue to be on renewable energy sources, ensuring that DH remains a cornerstone of Denmark's sustainable energy system.
- The report emphasizes the need to adapt to new technologies and evolving data for effective policymaking. Policymakers must respond to fuel price fluctuations, advancements in energy technologies, and shifting global economic conditions. The continued development of hydrogen, CO_2 capture, and biofuels is critical as Denmark transitions away from coal, oil, and natural gas toward a more electrified, biofuel-driven future.

The KF24 report confirms the vital role of DH in Denmark's green transition. It highlights how DH systems are developing to incorporate renewable energy and align with the country's broader climate goals. By 2030, DH is expected to be a leading model of sustainability, primarily driven by wind, solar and biofuels, as shown in Figure 8, ensuring that Denmark meets its ambitious emission reduction targets.

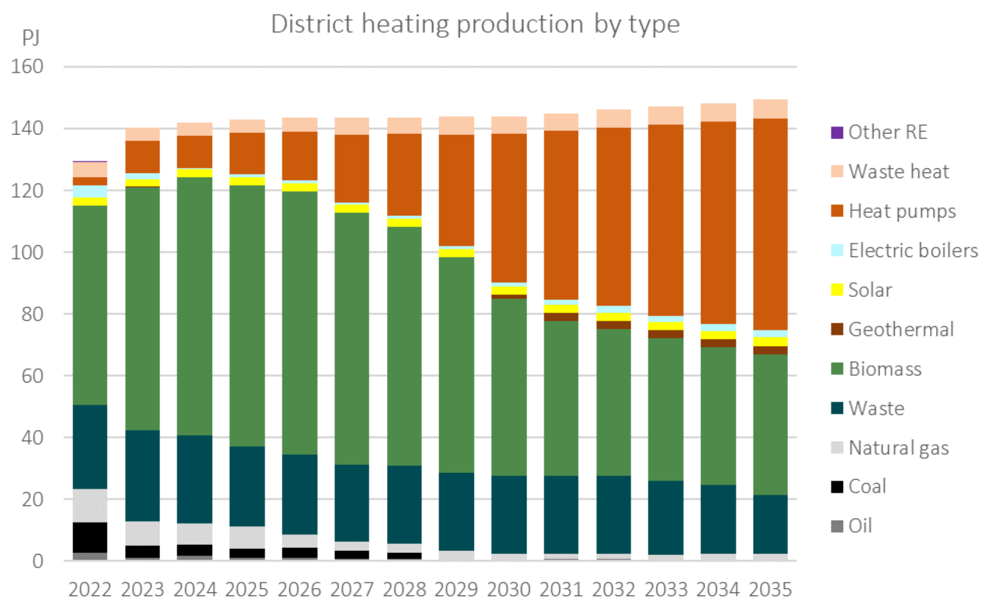


Figure 8 - Projected district heating production by type. Ref.: KF24

DH technology trends

Increased sector integration

DH systems are increasingly leveraging their potential to integrate with other energy-consuming sectors, a process known as sector integration or sector coupling. This approach can reduce energy waste, boost renewable energy utilization, and support decarbonization efforts.

For DH, key areas of integration include:

- Industrial sector
  Many DH networks capture surplus heat from industrial processes that would otherwise be wasted. Waste heat from wastewater treatment plants is also captured and used in DH systems. If the surplus heat is sufficient, typically above 70°C, it can be fed directly into the DH network. For lower temperatures, heat pumps are installed to raise the temperature to the required level.
- Digital infrastructure

  The expansion of digital infrastructure, particularly new data centers, has led to a significant increase in cooling systems usage. These systems provide a continuous source of low-temperature waste heat, which, when upgraded with heat pumps, can meet DH temperature requirements.
- District cooling systems

  In addition to DH, an increased number of district energy systems also provide cooling by using heat-driven absorption chillers or electric heat pumps that simultaneously produce heat and cooling.
- Electricity sector

  Several technological advancements enhance the flexibility of DH and CHP systems, helping integrate fluctuating energy from wind and solar PV. Key solutions include:
  - Heat storage

    Widely implemented in Denmark, heat storage systems allow DH and CHP plants to optimise production based on electricity prices and market conditions. For instance, when wind turbines and solar PV supply sufficient electricity, CHP production is reduced, while heat demand is met from thermal storage.
  - Electric boilers

    These enable DH systems to directly utilize surplus electricity from wind and solar PV for heat production, while also providing services in auxiliary energy markets.
  - Large electric heat pumps

    These maximize economies of scale by upgrading low-temperature waste heat to usable DH temperatures. They offer high flexibility since they can be paused when necessary, with full backup capacity typically available in Danish DH systems.
  - Bypassing steam turbines

    This allows thermal CHP plants to halt electricity generation when there is an excess supply of electricity in the grid. Instead, they function like a heat-only boiler, with similar efficiency.

This setup acts like a "virtual battery": when there is excess electricity and low prices, DH companies use heat pumps and electric boilers to produce heat, storing it for later use, while the CHP plants produce heat only. When electricity prices are high, heat pumps are turned off, and CHP plants take over, producing both heat and electricity. Besides the benefits for the DH system, this combination helps to balance the electricity grid.

A growing number of large heat pumps

In recent years, large electric heat pumps have been increasingly integrated into DH systems, utilising low-temperature heat from sources such as ambient air, industrial processes, data centers, cooling systems, wastewater, seawater, groundwater, and deep geothermal heat.

These heat pumps upgrade extracted heat to a usable temperature for DH. They can operate as a base load or only when electricity prices are low, making their operation cost-effective. To ensure stable heat supply, an alternative heat source is typically required to cover heat demand when the heat pump is not running.

Denmark has been at the forefront of integrating large-scale heat pumps into its DH infrastructure. Some notable projects include:

- DIN Forsyning (Esbjerg): Two seawater heat pumps with a combined capacity of 70 MW, commissioned in November 2024, extract energy from the North Sea. This facility, the world's largest CO_2-based seawater heat pump, supplies DH to Esbjerg and Varde.
- Aalborg Forsyning (Aalborg): A 176 MW seawater heat pump, expected to be operational by 2028, will harness energy from Limfjorden and cover nearly one-third of the city's DH demand - a key part of Aalborg's strategy to replace coal-based DH with greener alternatives.
- HOFOR (Copenhagen): Plans for large-scale heat pumps with a total capacity of 300 MW, which will cover 25-30% of Copenhagen's heat demand. One facility, located at Tietgensgade, will feature a 5.2 MW heat pump, expected to generate 23,000 MWh of heat annually, equivalent to the heating needs of nearly 3,000 apartments.[4]

  Besides this new installation, HOFOR currently operates three additional heat pumps with a total capacity of around 10 MW, including:

  - A seawater/wastewater heat pump
  - A groundwater heat pump
  - A heat pump that recovers surplus heat from Novonesis' enzyme production.

These projects highlight Denmark's commitment to sustainable heating solutions, integrating seawater heat pumps as a key component of the energy transition while optimising their operation based on electricity price fluctuations.

[4] Based on an average yearly consumption of 7,7 MWh/apartment according to https://danskfjernvarme.dk/viden-vaerktoejer/udgivelser/opdateret-definition-af-fjernvarmens-standardhus

Electric boilers

With a high share of wind and solar PV in Denmark's electricity system, there are periods when power generation exceeds demand. During these times, electric boilers help convert surplus electricity into heat.

Electric boilers offer low investment costs and fast reaction times, making them ideal for load balancing in the electricity system and an effective supplement to electric heat pumps.

Over the past five years, Denmark has installed around 2,000 MW of electric boiler capacity, with further expansion expected. These boilers dominate the market for down-regulation services in the electricity system, absorbing surplus electricity production from wind and solar PV.

The value of thermal energy storage

Nearly all DH companies in Denmark have installed thermal energy storage (TES) facilities to enhance flexibility and efficiency in heat production. Heat storage allows DH systems to effectively utilise various energy sources, even when they don't align that may not align with variations in heat demand. Both large- and small-scale DH systems benefit significantly from having thermal storage capacity.

For large CHP plants, which can also operate in condensing mode[5] (heat extraction plants), hot water storage tanks allow the plant to generate maximum electricity during peak power demand hours.

For smaller CHP units, such as engines or back-pressure steam turbines, hot water storage tanks enable the plant to adjust its output based on the electricity market. When there is a shortage of electricity in the grid, the CHP units can increase electricity generation, even if there is low heat demand in the DH network. The produced excess heat is stored in the thermal tank and utilised later when the heat demand increases.

While hot water storage tanks are widely used for short- to medium-term storage, balancing daily heat production and consumption, some DH systems employ longer-term heat storage solutions, such as pit thermal energy storages (PTES) or in some cases borehole thermal energy storage (BTES). This includes seasonal heat storage, where excess heat produced in the summer, e.g., from a solar heating plant, is stored for use in the colder months when heat demand is higher. Aquifer thermal energy storages (ATES) can also serve as thermal reservoirs, although this has only been implemented on a smaller scale in Denmark, often as dual operation with both DH and cooling systems.

In recent years, TES has become increasingly important as many DH companies operate electric boilers to participate in electricity market regulation. During periods when renewable electricity generation exceeds demand, DH companies use electric boilers to convert excess electricity into heat, storing it for later use. For biomass boilers, which are also widespread in Denmark, heat storage allows the boiler, which normally has limited regulation ability, to operate efficiently at a constant, optimal load by storing excess heat during periods of low demand.

5 When steam turbines are used for co-generation, they can be designed as backpressure turbines using the entire waste heat or as extraction condensing turbines with controllable waste heat utilisation. In contrast, a condensing turbine produces only electricity, while all the waste heat is dissipated into the environment, as in nuclear power plants.

Geothermal heating

Geothermal energy, a renewable resource derived from the Earth's internal heat, presents a sustainable and renewable solution for DH systems. Utilising geothermal energy for DH leverages consistent heat from geothermal reservoirs, ranging from shallow subsurface hot water aquifers for ground-source heat pumps to deeper geothermal systems tapping into high-temperature hot water aquifers and geothermal hotspots.

A few kilometers below the Earth's surface, hot water flows through cavities between porous sandstones. Across large areas of Denmark, this hot water flows freely, forming vast reservoirs of hot water that can be pumped to the surface and used as a renewable heat source. Due to Denmark's specific geological characteristics, geothermal energy typically requires heat pumps to be effectively utilised.

Denmark currently has three geothermal plants:

- Thisted: Operational since 1984, with a geothermal heating capacity of 8.6 MW.
- Copenhagen (Amager): Commissioned in 2005, with a capacity of 14 MW.
- Sønderborg: Established in 2013, with a capacity of 10 MW.

In addition to the existing facilities, there are ongoing efforts to expand geothermal energy in Denmark:

- Aarhus is developing a large-scale geothermal plant expected to cover approximately 20% of the city's DH demand, with a planned capacity of 110 MW.
- Høje Taastrup is in the process of planning a new geothermal plant with a capacity of 26 MW.

Initial studies[6] indicate that geothermal heat has great potential in Denmark. In the future, it may be able to supply around 15% of the heat demand in the DH sector.

Low-temperature DH systems

In many Danish DH networks, the supply temperature typically ranges around 80°C or higher, with the return temperatures between40-45°C. To improve efficiency, most DH companies encourage consumers to reduce return temperatures through informational campaign and incentive-based tariffs (e.g., a bonus for achieving a lower return temperature). Many DH companies are also working to reduce supply temperatures in their network as much as possible and encourage the consumers to be “low-temperature consumers” by adjusting their internal heating systems and hot water production to the lowest possible temperatures, while maintaining the necessary standards to avoid the risk of legionella.

In some cases, supply/return temperatures as low as 60/35°C have been achieved. To lower DH supply temperature, older buildings may need upgrades (e.g. radiators and insulation) to prevent critical deterioration of thermal comfort will deteriorate. An option in new urban developments is a three-pipe system in which underfloor heating is operating at 40/25°C supply/return and domestic hot water at 60/25°C supply/return.

[6] https://ens.dk/media/1139/download

Lower operation temperatures in a DH system have several advantages:

- Reduced heat losses in the pipeline network and lower operational cost associated with heat losses.
- Lower return temperature increases the capacity of the network or allows the DH company to reduce the supply temperature.
- Lower return temperature increases efficiency of thermal heat production, especially with flue gas condensation.
- Enhanced efficiency of heat pumps while enabling the use of low-temperature heat sources for DH production.

Several existing DH areas have successfully reduced the temperature level in the DH network over the last few years. Particularly for large networks, it is important that the temperature level is continuously optimised (online optimisation) according to the actual demand in the DH network.

Digitalisation in DH systems

For over 40 years, DH companies in Denmark have leveraged digital tools for planning and operation of heat supply, e.g., geographic information systems (GIS), hydraulic analysis tools, load dispatch optimisation tools, systems for billing and accounting, operation and maintenance systems and SCADA (Supervisory Control and Data Acquisition) systems. In recent years, these tools have been supplemented by GPS systems and, not least, electronic remote readable heat meters.

These heat meters have improved the communication between DH companies and consumers as well as system optimisation and quality of supply. This contributes to ensure that all consumers have the lowest possible but sufficient supply temperature and give consumers immediate feedback in case of unexpected increase in return temperature and demand.

However, DH companies delivering heat in smaller villages are typically not fully digitalised, as the costs may surpass the potential benefits, leading to higher expenses for both customers and providers.

The demand for new technologies

With the goal of 70% reduction in the emissions by 2030 and climate neutrality by 2045, there is a need there is a need for new technologies and tools. In a future where sectors are increasingly interconnected and digitalised, innovative technologies will play an important role in minimising emissions, especially in areas that were previously challenging or impossible to decarbonise.

Key technologies driving this transition include Power to X (PtX), Carbon Capture Storage (CCS) and Carbon Capture Utilisation (CCU), all of which with significant investments being directed towards their development and implementation.

Across the energy, transport, and industrial sectors, the focus remains on electrification, driving a steady increase in electricity demand. In the energy sector, this includes a growing use of heat pumps, both for private households and in large-scale DH networks, along with increasing deployment of electric boilers for DH generation.

Key trends include:

- Electrofuels from PtX plants will be essential for reducing emissions in the transport and industrial sectors. While the transport sector is already undergoing massive change through electrification and the implementation of electric vehicles, electricity remains unviable for heavy transport (land, sea, air) and industrial processes.
- The production of hydrogen generates substantial surplus heat, which can be efficiently utilised in DH networks, either directly or through large heat pumps.
- CO_2 emissions from waste-to-energy plants, biomass-fueled facilities, and biogas-to-biomethane upgrading plants will serve as valuable resources for production of electrofuels based on hydrogen (CCU), or be stored underground (CCS), further aiding decarbonization in sectors where electrification is not viable.

6. The Danish district heating industry

Denmark is a global leader in DH, having developed cutting-edge technologies and deep expertise in establishing cost- and energy-efficient high-quality DH systems. This success has been fueled by strong collaboration between DH companies, consultants, and policymakers, supported by stable Danish energy policies.

Due to Denmark's advanced DH sector, many companies involved in the DH sector, specialising in design, engineering, construction, and manufacturing of DH components originate from Denmark. These companies have also expanded internationally, exporting innovative Danish solutions worldwide.

For example, pre-insulated pipes, initially developed in Denmark, have become an international standard. These pipes are continuously optimised through smarter construction techniques and better operation. This results in cheaper implementation and longer technical lifespan (expected 60+ years, up to 100 years for low-temperature systems).

The Danish DH industry consists of manufacturers, consulting firms, and utilities, covering:

Manufacturing of components for DH, e.g.:

- Biomass boilers
- Large heat pumps
- Electric boilers
- Heat exchangers
- Heat meters
- Large scale solar water panels
- Controls and heating transfer solutions
- Pumps and pump systems
- Pre-insulated pipe systems
- Power and automation technologies
- Solutions for metering electricity, heating/ cooling, water, and natural gas.

Consultancy expertise within:

- Energy planning and energy system analyses including analyses of CHP and DH
- Conceptual planning and design of DH systems
- Usage of surplus heat from different industries
- Optimal operation of DH systems including temperature optimisation
- Low temperature systems and integration of different renewable technologies into a DH system
- Combined heating and cooling
- Utilities' hand-on experiences with operating all the Danish DH systems of different sizes and types and based on different heat sources

Furthermore, Danish research institutions and universities have gained world leading academic knowledge, conducting R&D activities within DH systems, components, heating production and system integration.

Danish manufacturers cover the entire DH supply chain, from heat production, transmission, and distribution to building installations including metering systems. The global success of Denmark's DH industry stems from decades of experience with DH in Denmark and a strong focus on high quality products, ensuring long-term performance and reliability.

Danish consulting companies specializing in energy planning, production and efficiency have been active throughout the development of DH. In the early phases, they assisted municipalities with heat supply planning and DH companies with implementing production plants and DH networks. The collaborative ownership structure of DH companies has facilitated knowledge-sharing, enabling consultants to transfer best practices across Denmark and internationally.

Today, consultants assist national and local authorities analyse DH's role within the broader energy system. They also support utility companies in continuously developing and optimising DH systems and integrating renewable technologies.

Denmark's dedicated DH industry, backed by decades of expertise, remains at the forefront of energy-efficient heating solutions. With continued innovation, collaboration, and global expansion, Denmark's district heating sector is poised to play a pivotal role in the international energy transition.

7. Green global assistance

Denmark fosters bilateral government-to-government cooperation with several countries, sharing the Danish expertise in mitigating greenhouse gas emissions while sustaining economic growth. The Danish approach serves as a catalyst for other countries to modernise their energy systems and achieve their climate goals.

The DEA offers global assistance in scenario modelling, renewable energy, energy efficiency and district heating. By cooperating internationally, the DEA aims to assist all partners towards a cleaner and more reliable future energy system by supporting capacity building efforts, achieving concrete energy savings and emissions reductions, as well as promoting government collaboration through expert consultancy.

As a secondary and derived focus of the DEA, spotlighting Danish strongholds in green solutions, can be an expanded market for Danish energy products and solutions through the Energy Governance Partnership (EGP). This may open up further trading collaboration both directly and indirectly.

Focus on growth economies

Geographically, the assistance of DEA concentrates on growth economies. Denmark currently cooperates with China, Brazil, India, Türkiye, Indonesia, and Ukraine among others. In these regions, Denmark's energy system design expertise contributes to rebuilding and modernizing energy infrastructure, fostering sustainability, resilience and flexibility across diverse energy sources.

DEA provides guidance and expert consultancy within the following fields:

- Long-term energy modelling and scenarios
- Integration of renewable energy in the energy system
- Wind power – offshore and onshore
- Energy efficiency – industry and buildings
- District heating

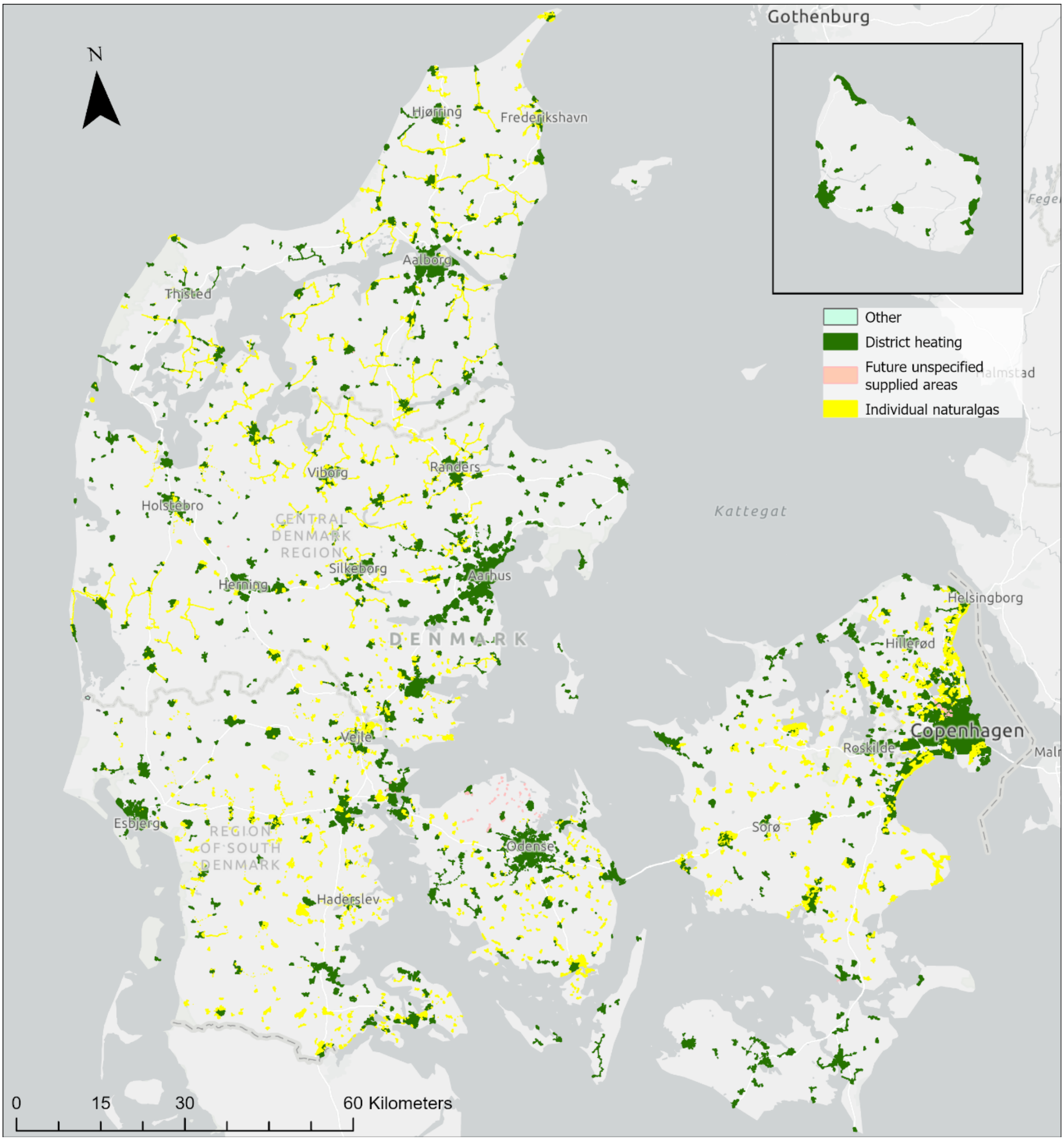
Combining sustainable future energy with viable growth

The DEA's global guidance supports partner nations in anticipating future energy demands and incorporating higher shares of renewable energy into their supply systems. This approach ensures that sustainability and economic viability go hand in hand, creating efficient, future-proof energy solutions.

8. List of Abbreviations

Abbreviation	Full Term
CHP	Combined Heat and Power
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
DEA	Danish Energy Agency
DH	District Heating
DUR	Danish Utility Regulator
EED	Energy Efficiency Directive
ETS	Emissions Trading System
GIS	Geographic Information System
KF24	Climate Status and Projections 2024 (Klimastatus og Fremskrivninger 2024)
LCOE	Levelised Cost of Energy
PJ	Petajoule
PtX	Power-to-X
PV	Photovoltaic
SCADA	Supervisory Control and Data Acquisition

9. Appendix 1 - Map of Denmark's heating supply



10. Appendix 2 - District heating timeline

1900s-1950s	1970s-1980s	1990s-2000s	2010s	2020s
Early development	**Oil crisis and policy shifts**	**Energy transformation**	**Towards fossil-free future**	**More integration of renewable energy**
• Establishment of the first district heating (DH) system in Copenhagen in 1903 • Post-World War II: expansion of DH in large cities	• First Heat Supply Act (1979) • Promotion of DH and CHP using coal and gas • Possibility to make connection to DH or gas grids mandatory (1980s-2019)	• Decentralisation of heat planning to municipalities • Promotion of decentralised CHP using local resources • Biomass starts to gain importance	• Energy Strategy 2050: a fossil-free Denmark by 2050 (2012) • Plan initiated to end coal use in DH by 2030 (2016)	• Phasing out natural gas • Electrification of DH