Inflight Magazine

# District heating: A Swiss army knife in transforming future energy systems

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District heating: A Swiss army knife in transforming future energy systems

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## Foreword

# Welcome to Denmark's district heating system

**Denmark is embarking on a transformation of its energy system, charting a course towards a low-carbon future. This transition is underpinned by a steadfast commitment to resource efficiency, with a particular emphasis on optimising energy consumption in buildings, industry, and transportation.**

To push the needle, Denmark regards the role of public-private partnerships as a key in driving innovation and investment in the energy sector. These partnerships serve as the linchpin of the Danish transition strategy, fostering collaboration between governmental entities, private enterprises, and research institutions. By harnessing the expertise and resources of both the public and private sectors, Denmark can accelerate the development and implementation of cutting-edge technologies and practices.

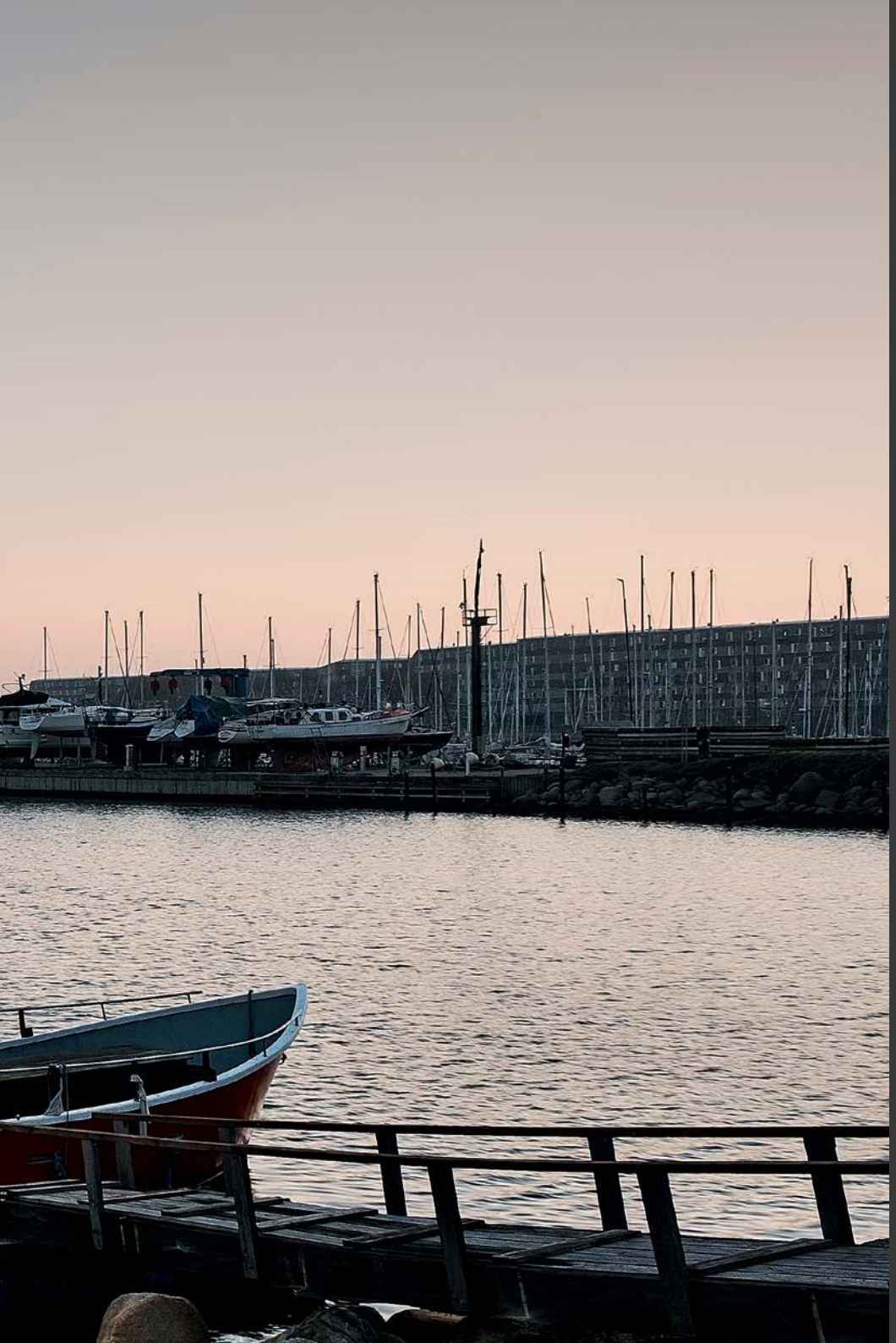
While early initiatives focused on implementing solutions at home, Denmark's approach to energy transition transcends its borders. International collaboration is instrumental, notably in the Danish tie-up with Germany. The German-Danish cooperation is crucial in building an integrated and resilient energy network. By working together, Germany and Denmark can continuously co-create a regional energy ecosystem that maximises the potential of fluctuating renewable sources like wind and solar while utilising surplus energy and heat from various sources and exploring innovative approaches, such as green hydrogen. To the benefit of both societies, the partnership entails the exchange of knowledge, expertise, and best practices in areas such as renewable energy production, grid management, and energy storage solutions.

District energy systems in particular play a pivotal role, as they tie together various elements of the future's energy mix by integrating electricity, heat, cooling, transport, and renewable fuel production. These district energy systems

are becoming increasingly data-driven, thanks to the active involvement of district energy companies across the value chain. By harnessing data and employing advanced analytics, these companies optimise their operations, enhance energy efficiency, and contribute to the overall journey of Denmark's energy transition.

Examining what's in store for future district heating systems, I hope this catalogue will provide Danish insights and serve as an inspiration to follow.

**By Finn Mortensen**
**Executive Director, State of Green**



# Content

## Introduction



## Solutions

# How district heating is paving the way towards Denmark’s climate goals

## What is Denmark aiming for?

By law, Denmark is committed to reduce its greenhouse gas emissions by 70 percent by 2030 compared to 1990 levels, striving for net-zero emissions by 2050. To reach these targets, the implementation of district heating and cooling throughout the country plays a central part.

By moving energy in water, with a valuable temperature, from a place of production to a place of consumption, district energy can be used to secure an energy-efficient heating and cooling supply through a collective system.



### Denmark’s climate ambitions

- → **Net-zero by 2050**
- → **Reduce greenhouse gas emissions by 50-54% by 2025 and 70% in 2030**

District energy not only reduces carbon emissions from the heating and cooling sector, but also supports the integration of renewable energy sources, enhances energy efficiency, and ensures a reliable and sustainable energy supply. This has made district energy a linchpin in Denmark’s strategy to meet its climate goals.

## Where do we come from?

The Danish journey of district heating began in 1979 with the passage of the first heat supply law. This marked the beginning of a transition that has not only changed how Danes heat and cool their homes, but has since become a global benchmark for energy solutions.

Over the years, Danish stakeholders have forged a robust political framework, which facilitated the implementation of district heating and simultaneously enabled the acquisition of four decades of invaluable expertise along the way. This has spurred a number of companies specialising in cutting-edge technologies with comprehensive competencies across the entire spectrum of district energy systems’ value chains.

And the speed at which the district heating sector has developed in Denmark has been made evident by how rapidly the sector's emissions have fallen.

At the beginning of the 2010s, Denmark’s electricity and district heating sectors, excluding waste incineration, accounted for about 30-40 percent of Denmark’s total emissions of greenhouse gases.

However, projections from the Danish Energy Agency suggest that by 2025, the share of emissions from the electricity and district heating sector will drop to just 3 percent, and by 2030, emissions are going to account for less than 1 percent of Denmark's total net emissions. This is equivalent to a mere 0,1 million tonnes of $CO_2e$.

## Where is Denmark today?

In contrast to many other nations that rely on standalone heating and cooling systems, Denmark has made a strategic shift towards communal heating systems following the 1970s oil crisis. Today, energy-efficient heating and cooling solutions are deeply ingrained in the Danish mindset.

In Denmark, district heating supplies about 70 percent of the heating demand from buildings, with 35,000 new connections occurring in 2022. Denmark's district heating system is highly energy efficient and has been one of the key drivers for reduced energy consumption and $CO_2$ emissions from the energy sector. Roughly two-thirds of the energy used for district heating across Denmark comes from renewable energy and waste heat.

The efficiency of Denmark's district energy system rests on three core components: the distribution of heating or cooling water, the minimisation of energy loss during distribution, and the effective connection of district

PHOTO OF THE CHP PLANT AMAGER BAKKE IN COPENHAGEN

CHP PLANTS

### Energy-efficient heating and cooling

District energy systems are a highly viable solution for meeting the heating and cooling needs of densely populated urban areas, smaller cities, as well as industrial zones. This is achieved through combined heat and power plants, also known as CHP plants, that enable efficiency levels surpassing 90 percent. CHP plants are, therefore, a cost-effective way of heating and cooling buildings and facilities.

In Denmark, the first CHP plant was built in 1903 as a waste incineration plant, making it possible to handle waste in a more sustainable way by providing both electricity and heat, in the form of steam, to a hospital. Therefore, the plant solved two problems at once.

energy systems to consumers. Therefore, district energy not only reduces carbon emissions, but also addresses energy poverty, by lowering energy bills for consumers.

Furthermore, Danish heating production is decentralised as production is generally reliant on being in close proximity to the consumers. This creates a natural monopoly in the industry, regulated by a non-profit principle; which dictates that the price of district heating must not exceed the cost of heat production.

Denmark's district heating landscape comprises six large central heating regions around major cities, and 400 smaller decentralised district heating areas, which together offer a comprehensive and versatile heating network.

## What did we learn along the way?

By 2030, there is a strong anticipation that wind energy will successfully meet 100 percent of Denmark's electricity demands. This achievement will lead to a significant emphasis on the development of adaptable district energy systems, vital for integrating wind power into the broader energy infrastructure. Consequently, district energy not only stands as a force in realising Denmark's climate objectives, but also plays an essential part in the orchestration of the future energy grid.

In summary, district heating safeguards that Denmark has a sound and reliable heating supply while greatly supporting its long-term energy policy targets.

70%

**In Denmark, district heating supplies about 70% of the heating demand from buildings, with 35,000 new connections occurring in 2022.**

FACTS

## Why district heating?

District heating represents an energy-efficient solution, that can assist in decarbonising energy systems, enhance energy security, and drive economic as well as environmental benefits:

**Clean energy integration:**
District heating can incorporate renewable energy like wind, biomass, and solar energy, reducing carbon emissions and helping nations decarbonising their energy systems.

**Efficient resource utilisation:**
Utilising waste heat from industrial processes maximises resource efficiency and minimises energy waste.

**Energy savings:**
Centralised heating systems can help optimise energy use, reducing heat loss and consumption, leading to long-term energy savings and lower energy bills for consumers.

**Versatility and adaptability:**
District heating systems can adapt to various heat demands in urban and rural settings, making them versatile and applicable across diverse regions.

**Reliability and resilience:**
District heating networks offer dependable heating services, even in extreme weather conditions, by enhancing energy security and ensuring uninterrupted services.

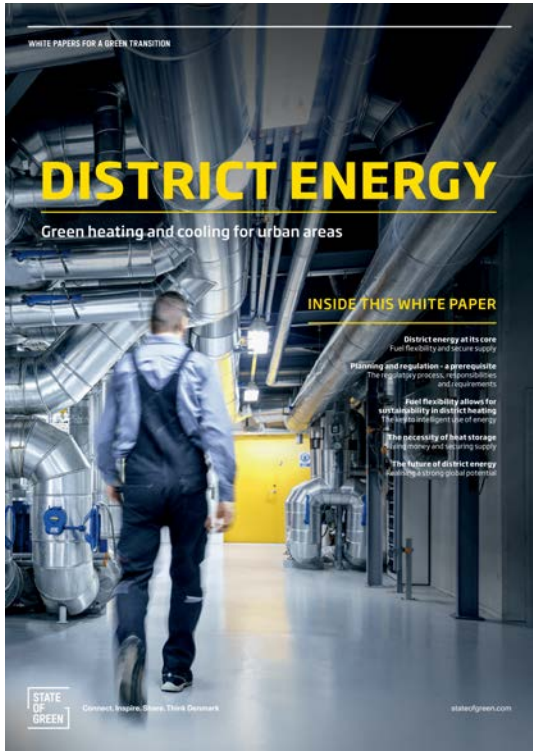
# White paper: District Energy

**Explore our white paper and discover how district heating and cooling ties Denmark's future energy system together, making it a central part of Denmark's green transition.**

Acting as a cornerstone in the Danish energy transition, district energy plays a central part in creating an inter-connected energy landscape where electricity, heat, cooling, transportation, and the production of renewable fuels are integrated.

By harnessing fluctuating renewable energy sources like wind and solar power, capturing surplus heat generated by industries, and leveraging its role in the production of green hydrogen and e-fuels, district energy acts as the linchpin that binds together Denmark's energy landscape.

Our white paper "District Energy: Green heating and cooling for urban areas" draws on competencies built up through more than 100 years of experience with district energy in Denmark as well as around the world. It highlights some of the main learnings to consider when expanding the use of district energy, such as the system, regulatory frameworks, planning, efficiency, flexibility of energy source, as well as storage and future perspectives, by including relevant cases from around the world.




DISCOVER

**White paper: District Energy – Green heating and cooling for urban areas**

With insights and perspectives from Ramboll Energy, Grundfos, COWI, HOFOR, and many more, the white paper covers everything from fuel flexibility and solar district heating to pipe systems and storage.

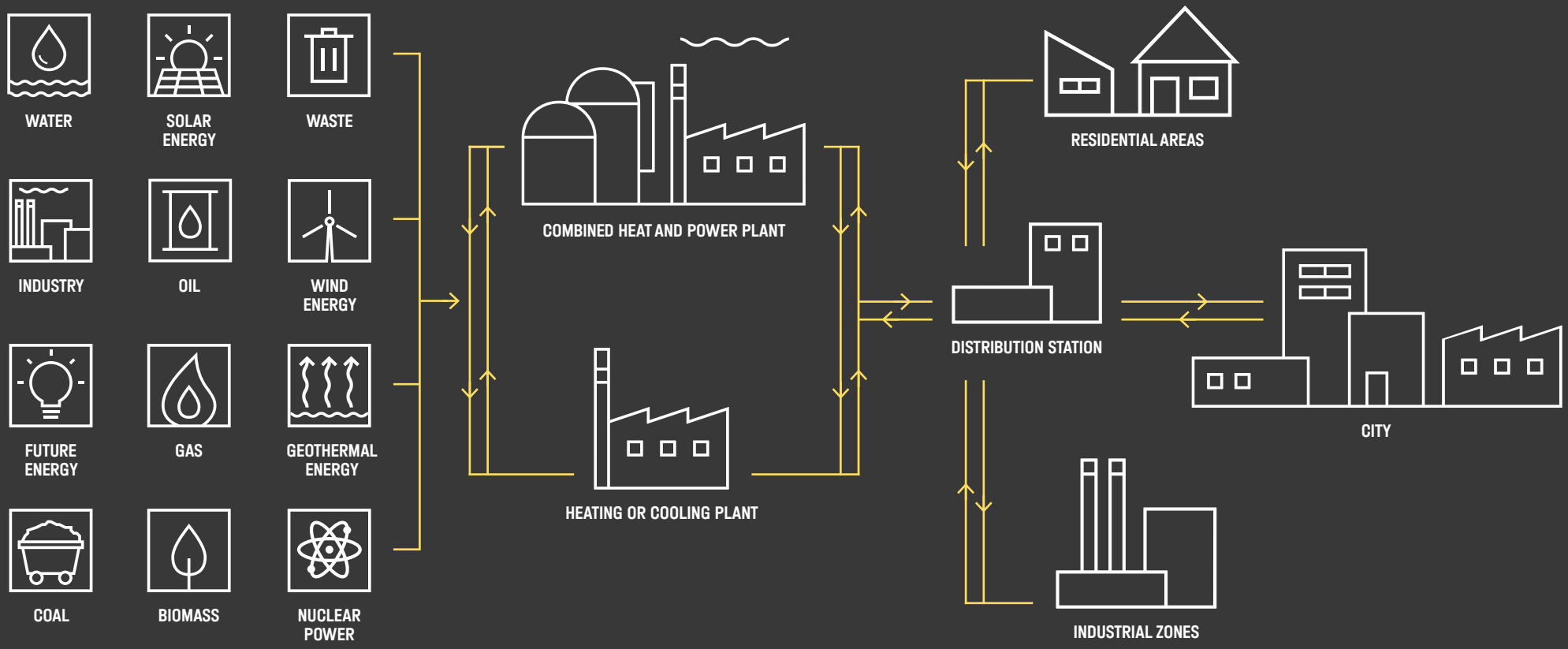
**Discover the white paper at stateofgreen.com/publications**

## Illustration

# Overview of a district heating system

Heat is either produced as surplus heat from many sources (left part of illustration), then pumped through highly effective district heating pipes to end users. Through the storage facility, it is possible to decouple production over short or longer periods of time – even months.

With several production facilities, the economy of the district heating system can be optimised continously. The end user will enjoy heat delivered from the best available source and not stuck with just one fuel option.



Cases

# Danish solutions within district heating

## Heat storage

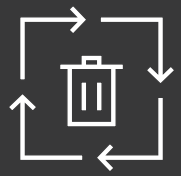
STORING HEAT FOR A COLD DAY IN DENMARK'S CAPITAL REGION

## Geothermal energy

JOINING FORCES IN AARHUS FOR EU'S LARGEST GEOTHERMAL HEATING PLANT

## Biomass & heatpumps

DECARBONISATION THROUGH BIOMASS AND HEAT PUMPS



## Waste to heat

PERFECTING PIPELINES ACROSS HAMBURG

## Combined heat & power production

EFFECTIVELY INCREASING RENEWABLE ENERGY YIELDS

PHOTO: PLANENERGI



**CASE 1** PLANENERGI
**TAG** HEAT STORAGE
**LOCATION** HØJE TAASTRUP, DENMARK

# Storing heat for a cold day in Denmark's Capital Region

## Challenge

In the journey towards establishing a fossil-free energy system, maintaining an equilibrium between energy consumption and production is pivotal. This balance needs to be economically viable, especially regarding the inclusion of a high share of fluctuating renewable energy sources.

Taking a significant step towards harnessing the potential of waste heat, Copenhagen has become the home of a collaborative initiative aimed at creating an innovative heat storage facility.

The Copenhagen district heating system consists of four Combined Heat and Power (CHP) plants, as well as three waste incineration plants. These CHP plants generate both heat and electricity simultaneously from a single source of fuel, and they capture and utilise the waste heat, which is otherwise lost in conventional power generation. This system is, however, inflexible, as the CHP plants produce electricity during periods of high wind and low electricity prices and can be forced to produce heat in periods with high electricity prices.

**Taking a significant step towards harnessing the potential of waste heat, Copenhagen has become the home of a collaborative initiative aimed at creating an innovative heat storage facility.**

## Solution

In an effort to add flexibility to the district heating system, Høje Taastrup District Heating and Vestegnens Kraftvarmeselskab I/S, VEKS, collaboratively opted to build a heat storage facility. This joint venture manifested itself in a subterranean cavity lined with a plastic membrane and a sealed lid on top. While Denmark already features several pit thermal energy storages (PTES), these predominantly serve as seasonal storage solutions linked with solar.

By effectively storing heat during periods of low electricity production costs and distributing it during times of high electricity cost, the facility extends electricity production incomes and contributes to the Copenhagen metropolitan area's green energy transition through better integration in the electricity system. However, this mechanism is not designed to supply heat back to the transmission grid.

## Result

The storage facility accommodates 70,000 m2 of water able to withstand a temperature of up to 90°C, which is new and requires a newly developed PP membrane to seal the storage facility and a change in the management of the Copenhagen district heating system. Additionally, it contains a charging and discharging capability of 30 MW and can store 3,300 MWh, contributing to a retained estimated annual value of approximately EUR 1,1m (DKK 8m) to the district heating systems across the entire Copenhagen metropolitan area from more flexible operation of CHP plants, replacement of natural gas used as peak load and more efficient utilisation of heat from waste incineration during summer.

Currently, the site has been in operation since the beginning of 2023.


PHOTO: PLANENERGI

PlanEnergi

## About

PlanEnergi is an independent engineering consultancy. Since its foundation in 1983, the company has been working on the transition to a 100 percent renewable energy supply. The assignments range from strategic energy plans and heat plans for regions and municipalities to design tenders and implementation of district heating, especially solar thermal, heat pumps, large heat storage, and biogas plants.

**Discover PlanEnergi at stateofgreen.com**

PHOTO: INNARGI



**CASE 2** INNARGI
**TAG** GEOTHERMAL ENERGY
**LOCATION** AARHUS, DENMARK

# Joining forces in Aarhus for EU's largest geothermal heating plant

## Challenge

Kredsløb, a utility group, owned by the Aarhus municipality, has the responsibility for processing waste as well as supplying the municipality with 90 percent of its district heating. However, Kredsløb needs to phase out 50 percent of its current biomass-based heat supply by 2030.

In a broader context, buildings and households collectively contribute to 13 percent of annual greenhouse gas emissions, which translates to a substantial 432,000,000 tonnes of $CO_2$ every year.

To address this issue, the partnership between Innargi and Kredsløb aims to resolve several challenges simultaneously.

Firstly, the utility seeks to achieve long-term stability in heat prices while reducing its reliance on unpredictable weather patterns and imported resources. Secondly, it aims to transition from heat generation via incineration to electrification, a crucial step towards establishing a truly carbon-free and future-proof energy mix. Additionally, the incorporation of electricity into the equation serves as a prudent portfolio risk hedge, whenever electricity prices are low.

## Solution

Innargi has entered a 30-year agreement with Kredsløb to develop and operate the largest geothermal heating plant in the European Union, located in Aarhus, Denmark. With large geothermal heating facilities, it will become possible to heat millions of homes with green energy, even when there is neither wind nor sunlight. Additionally, by replacing households' hydrocarbon-based heating sources, the average household's carbon footprint may be reduced by 6 tonnes every year.

The geothermal heating plant in Aarhus will embody 7 individual parts and 17 boreholes and supply the Aarhus municipality with 110MW and a supply of approximately 650,000MWh. The extracted water is pumped up from 2-3 kilometres below the surface, reaching a temperature of 60-80°C.

Upon reaching the surface, the heat contained within the geothermal water is efficiently harvested via a heat exchanger before being seamlessly integrated into the district heating network.

Once the heat has been utilised, the now-cooled geothermal water is reinjected into the subsurface, thus creating a self-sustaining and circular form of energy. This process offers a completely emission-free alternative to conventional base load energy sources like biomass, coal, and natural gas.

## Result

The Aarhus municipality contains a population of approximately 330,000 residents and is home to approximately 180,000 households, of which 95 percent of these are connected to the district heating grid. With the planned capacity of 110 MW, 20 percent of these households will be covered by the geothermal heating plant, with the first wave of heat already being delivered 3 months after the contract's signing.

Innargi's geothermal heating plant additionally offers the advantage of being weather-independent, showcasing stability and ensuring efficient utilisation of green electricity. This is achieved through a high coefficient of performance, which, in turn, results in a remarkable annual reduction of 165,000 tonnes of $CO_2$ emissions.


INNARGI

## About

Innargi is on a mission to heat millions of urban homes and provide clean and sustainable heat through geothermal energy, district heating networks, and industry. In close cooperation with district heating companies, Innargi develops geothermal projects with full economic responsibility for the subsurface and plant operation. The patented and modularised plant concept with a small footprint can be easily integrated into urban areas.

**Discover Innargi at stateofgreen.com**

PHOTO: LINKA GROUP



**CASE 3** LINKA GROUP
**TAG** BIOMASS & HEAT PUMPS
**LOCATION** EGTVED, DENMARK

# Decarbonisation through biomass and heat pumps

## Challenge

Egtved Varmeværk is a Danish district heating plant located in the town of Egtved in the Danish Region of Southern Denmark. The plant provides centralised heating to the local community, distributing hot water or steam to residential and commercial buildings for space heating and domestic hot water.

The plant set a goal to not only decarbonise its operations; it also aspires to provide consumers with the most competitive prices, expand its fuel options, and implement a robust, forward-looking integrated system, while ensuring operational safety.

## Solution

With considerations for the project starting back in 2009, and some assistance from Dansk Fjernvarmes Projektselskab, the choice fell upon Linka Group due to their ability to deliver a solution containing a high level of flexibility and security.

Linka Group provided a solution containing a fully automated combination plant consisting of a 2MW biomass plant as well as a 2,1 MW heat pump system, with a focus on user-friendliness and a healthy work environment for the operating staff.

Egtved's district heating plant transitioned to a sustainable energy solution by adopting a diverse range of renewable biomass resources, such as wood chips, straw, grain, and seed husks. This shift ensured a dependable and eco-friendly energy source. The introduction of this integrated system brought about a synergy between biomass and the heat pump which offered flexibility in energy utilisation.

14,000

**In 2021, Egtved Varmeværk's District Heating Plant reduced its annual $CO_2$ emissions by 14,000 tonnes.**

In relation not the transition, Anders Rønhof, Chairman of Egtved Varmeværk stated: "It was important for us to have a future-proof heating plant with the highest possible environmental profile and not just a boiler to burn wood chips."

A multiple choice of biomass could be employed during periods of high electricity prices, while the heat pump could efficiently operate when electricity prices were lower, thus optimising energy costs.

The collaboration between biomass, the heat pump, and the existing solar thermal plant enabled the district heating water to attain higher temperatures than what would have been achieved with a heat pump in isolation.

## Results

In 2021, Egtved Varmeværk's District Heating Plant reduced its annual $CO_2$ emissions by 14,000 tonnes. This achievement was made possible while maintaining a steadfast commitment to operational safety. Moreover, in the subsequent year of operation, the Egtved heating plant effectively lowered the average consumer price for heat.

The innovative multifuel biomass and heat pump solution introduced by Linka Group not only contributed to a substantial reduction in carbon emissions but, when combined with the existing solar thermal plant, also delivered a level of flexibility and reliability in energy generation.


LINKA group

## About

Linka Group are experts in the innovative technical development, optimisation, and operational support of energy plants for our future.

Having built more than 5,000 plants worldwide, Linka Group provides one of the broadest product ranges in the industry and offer biomass boiler systems for all professional purposes.

**Discover Linka Group at stateofgreen.com**

PHOTO: ADOBE STOCK

**CASE 4** KINGSPAN LOGSTOR
**TAG** WASTE TO HEAT
**LOCATION** HAMBURG, GERMANY

# Perfecting pipelines across Hamburg

## Challenge

Having served more than half a decade as a two-unit coal-fired power plant, the Wedel plant with a gross capacity of 289,7 MW, will gradually reduce its burning of coal by up to 30 percent, for the remainder of its operation.

Saving around 150,000 tonnes of coal, its closure contributes to a significant reduction in $CO_2$ emissions. However, the decommissioning of the Wedel plant necessitated alternative heat sources to be identified. This entailed an opportunity to increasingly feed climate-neutral waste into the district heating network. However, effectively preserving energy on its way through the district heating network poses another challenge.

## Solution

Climate-neutral waste heat generated by industrial processes, along with the planned wastewater heat pump project in southern Hamburg, presents an opportunity for harnessing significant heat resources.

**Climate-neutral waste heat generated by industrial processes, along with the planned wastewater heat pump project in southern Hamburg, presents an opportunity for harnessing significant heat resources.**

To fortify supply reliability for future urban expanses, a cost-effective solution entails the establishment of a cutting-edge KMR transport pipeline originating from the south of Hamburg. By tunneling under the Elbe, this southern pipeline will run to Bahrenfeld, where it will be connected to the western branch of the district heating network.

## Result

As a result, Nordic Harvest' plants thrive in a pesticide- The planned southern pipeline spans a total distance of 7,6 kilometres and is segmented into six distinct construction sections. Within this project, the installation of pre-insulated KMR-systems is planned for five of these sections. Notably, Kingspan LOGSTOR has been chosen as the supplier for material in three construction sections, accounting for a cumulative length of 5 kilometres.

The utilisation of Kingspan LOGSTOR's pre-insulated KMR in these sections stands to yield large energy-saving benefits, potentially reducing energy loss by a substantial 5,000 megawatt-hours annually.

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5,000

**The utilisation of Kingspan LOGSTOR's pre-insulated KMR in these sections stands to yield large energy-saving benefits, potentially reducing energy loss by a substantial 5,000 megawatt-hours annually.**

PHOTO: KINGSPAN LOGSTOR

Kingspan LOGSTOR

## About

With more than 50 years of research, development, and experience, Kingspan LOGSTOR is a leading manufacturer of pre-insulated pipe systems. With a strong focus on providing customers with better energy efficiency, the energy-efficient pipe systems ensure that only a minimum of produced energy is lost during transport over long distances.

**Discover Kingspan LOGSTOR at stateofgreen.com**

PHOTO: ADOBE STOCK



**CASE 5** EMD INTERNATIONAL
**TAG** COMBINED HEAT AND POWER PRODUCTION
**LOCATION** HVIDE SANDE, DENMARK

# Effectively increasing renewable energy yields

## Challenge

The district heating system situated in Hvide Sande, in the western part of Denmark, encompasses a variety of power generation and consumption units. It comprises a pair of heat storage tanks, a solar thermal plant spanning 9,576 m2, and three 3MW wind turbines (WTGs). These WTG's electrical output serve the dual purpose of both powering a 4,65 MW electric heat pump, as well as the 10 MW electric boiler used to produce heat. Furthermore, when electricity prices are high, the surplus electricity is vendored, and supplementary electricity can be generated by two natural gas-fired CHP units.

# 92.4%

**The solution assists in integrating fluctuating renewable energy production by scheduling the charging and discharging of storage accordingly, which is essential, as Hvide Sande District Heating e.g., produced 92.4 percent of the heat using renewable energy sources.**

This assortment of power generation units allows for a cost-effective production of renewable district heating solutions. However, orchestrating the day-to-day operations of the plant, and managing electricity procurement of the energy quantities remains a demanding task. The central intelligent control system must constantly make decisions about, which units to activate, and whether to engage in electricity purchases or sales across different electricity markets. The fluctuating and non-plannable renewable energy yield from the thermal solar installation and the wind turbines must also be factored into these decisions.

## Solution

EMD has successfully installed and implemented the energyTRADE software solution at the district heating plant in Hvide Sande. This innovative system continuously calculates the most optimal operation approach of the plant in real time.

Through a singular interface, the plant manager is provided with a detailed overview of the optimal operational approach and production schedule for the upcoming week. This comprehensive overview encompasses forecasts for renewable energy generation, the anticipated charging and discharging cycles of heat storage tanks, and whether the generated electricity will be converted into heat or sold off. The automated compilation of weather predictions and price projections of electricity, followed by their integration into an intricate plant model using Mixed-Integer Linear Programming (MILP), culminates in the attainment of an optimal production plan.

In cases where the ideal plan entails vendoring electricity, the software additionally determines the appropriate bids for electricity markets, enabling direct submissions.

## Results

The energyTRADE solution provided by EMD equips Hvide Sande District Heating with a swift overview and direct access to the most efficient operational schedule of the entire plant. This results in labour hour savings and more cost-effective heat production.

Additionally, the solution assists in integrating fluctuating renewable energy production by scheduling the charging and discharging of storage accordingly, which is essential, as Hvide Sande District Heating e.g., produced 92,4 percent of the heat using renewable energy sources.

PHOTO: EMD INTERNATIONAL

EMD International

## About

EMD is a software and service company with more than 35 years of experience in the renewable energy sector. EMD offers software solutions, service, training, and know-how for the development and operation phases of wind farm and hybrid projects as well as a wide range of energy systems such as neighbourhood concepts, and district heating up to P2X applications.

**Discover EMD International at stateofgreen.com**

## About State of Green

State of Green is a not-for-profit, public-private partnership between the Danish government and the country's three leading business associations (Danish Industry, Green Power Denmark, and the Danish Agriculture and Food Council). State of Green is your one-stop-shop to more than 600 Danish businesses, agencies, academic institutions, experts, and researchers. State of Green connects you with leading Danish players working to drive the global transition to a sustainable, low-carbon, resource-efficient society.

Learn more about district energy, discover cases and solutions, and connect with Danish expertise at:

**stateofgreen.com**

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