LOW-CARBON DISTRICT ENERGY

HANDBOOK BY THE
DANISH DISTRICT ENERGY ADVISORY

MINISTRY OF FOREIGN AFFAIRS
OF DENMARK
The Trade Council

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PURPOSE OF THE HANDBOOK

This handbook draws on the Danish experience of planning and implementing low-carbon district energy projects. The Danish District Energy Alliance (DDEA) have developed this handbook to foster a greater awareness of district energy's potential to enhance energy efficiency, reduce environmental impact, and bolster resilience, which are paramount in the built environment of today.

This handbook serves several vital objectives. First and foremost, it functions as an educational resource designed to enlighten readers about district energy, its historical development, and its numerous advantages.

This handbook also addresses the practical aspects of district energy systems, offering insights into the challenges associated with their implementation in North America. From daunting upfront costs to regulatory and market barriers, the handbook is intended to guide readers through potential hurdles, allowing designers, owners and consultants to better navigate and overcome them. The handbook will empower professionals and stakeholders with the knowledge to make more informed decisions regarding DE projects.

Furthermore, this handbook celebrates innovation and best practices by spotlighting successful district energy projects in North America. Through showcasing real-world case studies and examples, the DDEA encourages the exploration of diverse energy sources and inspires creative solutions.

Lastly, by delving into the historical context of district energy, the handbook showcases the evolution and growth of these systems over time. This historical perspective offers invaluable insights into the development of district energy, providing a solid foundation for understanding its contemporary applications.

For more information on low-carbon district energy systems and implementation in North America, please get in touch with the Gustav and Max at the DDEA:

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1. OVERVIEW OF DISTRICT ENERGY

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1. OVERVIEW OF DISTRICT ENERGY

1.1 WHAT IS DISTRICT ENERGY?

District energy (DE) systems provide heating and/or cooling from a central plant or several plants/ sources to individual buildings through underground pipes. DE networks are used to efficiently heat and cool multiple buildings using less fuel and operating more efficiently than if the individual building were to each have their boilers and chillers.

A network of underground pipes distributes water or steam connected to a central location (also known as an energy centre). Major heating and cooling production equipment are strategically positioned in a network to best serve the needs of customers while also considering larger planning efforts. A heating DE system consists of two pipes in each direction, one with hot water or steam and a return with colder water or condensate to be returned to the DE energy centres to be reheated and recirculated. In a cooling district system, one pipe will have cold water, and a return pipe with warmer water to be returned to the DE energy centre, where the heat is extracted and the water recirculated.

DE systems are not sustainable by nature, but a well-designed and constructed system is an efficient energy distribution systems. DE systems can use nearly any fuel source to heat or cool the water, including renewable and low-carbon fuel sources, making a more sustainable system. DE systems are used to provide energy more efficiently because they use centralized systems rather than individual stand-alone systems. Economies of scale are also gained given the cost advantages of larger centralized systems which are more industrial, have longer operating lives and can expand operations relatively cost effectively.

These systems are operated by professionals incentivized to provide cost-effective, reliable and resilient energy services because they "sell" the energy they produce. This enables building owners to focus on building operations and frees up building space that can be monetized. Owners of DE systems are incentivized to drive down costs, and focus on installing reliable and resilient distribution systems for their clients. An analysis of life cycle costs tends to show that DE results in lower costs when compared to conventional systems. In addition, DE systems free up space inside the building because pumps and heat exchangers replace the stand-alone heating and cooling plants (i.e. boilers, chillers and cooling towers).

1. OVERVIEW OF DISTRICT ENERGY

1.2 WHAT IS COMBINED HEAT AND POWER?

Combined heat and power (CHP) is a system where electricity is by an engine or a generator, and the waste heat from the electricity production is used for district heating (or district cooling with the addition of an absorption heat pump). The electricity is then distributed through the existing electrical grid. The energy efficiency from producing electricity alone is typically below 45% as the waste heat is not utilized. Combining electricity and district heating production can provide energy efficiencies of up to 90% [1]. Similar to DE, many different fuels can be used to produce electricity. CHP systems can use renewable or low-carbon fuel sources, making a more sustainable system. It is important to note that when converting an electrical power plant to a CHP plant, total electricity production and efficiency slightly decreases, as a result of the high temperatures that are required to be generated by the power plant in order to be used by the district heating system.

Waste incineration CHP plants are facilities that burn solid waste materials to generate heat and electricity while reducing the waste volume destined for landfills. The process begins with waste collection and preparation, followed by combustion in a high-temperature chamber. The heat produced during combustion is harnessed to generate steam, which powers a turbine to produce electricity. Pollution control technologies are employed to minimize emissions of pollutants, including fine particulate matter and harmful gases. The electricity generated is typically used to power the incineration plant, and surplus electricity is provided to the utility. The recovered heat is utilized in DH, industrial processes, or nearby buildings. Residues such as ash are managed and, in some cases, repurposed. Waste incineration plants offer an effective waste management solution while contributing to energy generation and reducing the environmental impact of waste disposal.

A similar process to waste incineration is employed by biomass and biomass CHP plants. Biomass can be imported or locally sourced and burned to generate heat and electricity for the district heating network and local utilities. Residues from biomass plants can then also be repurposed and transformed by use in other sectors, such as the construction industry.

Biomass CHP plants can also be extremely efficient. For example, Avedøre Power Plant in Denmark is one of the world's most efficient of its kind, being able to utilize as much as 94% of the energy in the fuel (straw and wood pellets) and convert 49% of the fuel energy into electricity.

1. OVERVIEW OF DISTRICT ENERGY

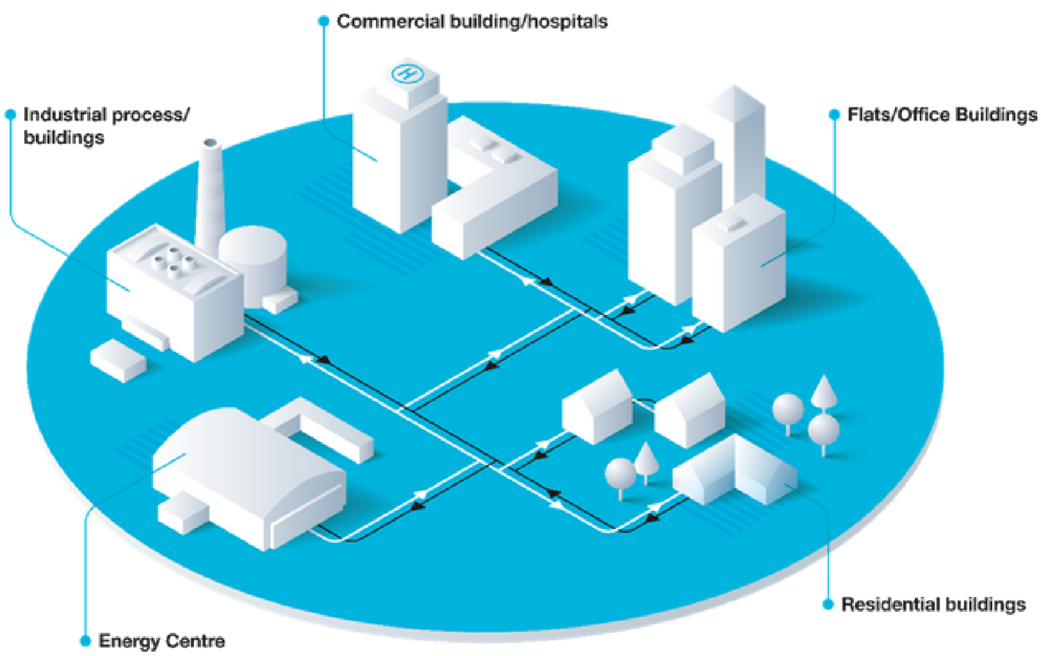
1.3 WHAT IS DISTRICT HEATING?

Below is an image from FLEXIS [2] that provides a simple diagram of a district heating (DH) system. DH is a system in which water is heated in one or several energy production units, then delivered via a network of buried pre-insulated pipes to the individual buildings. The heat from the water is extracted in a water-based heat exchanger, passed through a heat pump or directly piped into the building system hydronic system. The widespread use of DH and CHP is the main reason Danish cities can increase energy efficiency, drastically reduce carbon emissions and improve air quality over several decades.

For example, Aarhus, Denmark's second biggest city, has heavily invested in CHP plants that utilize biomass and natural gas to produce electricity and heat. Aarhus has met their energy needs while curbing greenhouse gas emissions, further contributing to national emission reduction targets. Another example is the town of Middelfart, where the DH networks are powered by waste incineration facilities, which ensures sustainable energy generation across long-term time horizons.

1.4 WHAT IS DISTRICT COOLING?

District cooling (DC) is a system in which water is chilled in one or several energy production units from electric or heat-driven chillers (absorption chillers). DC systems can use also water from large water bodies including lakes and oceans, such as Enwave's deep lake cooling system in Toronto, Canada. Once cooled, the chilled water is delivered via pipes to the building or structure. Heat from the building is transferred into the chilled water via a heat exchanger. DC reduces energy consumption by 50% or more by replacing inefficient building cooling units with more efficient units and reduce carbon emissions [3].



2. HISTORY

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2. HISTORY

The push for Denmark to start developing and upgrading these steam DH systems was when the oil crisis hit Europe in the 1970s. At that time, Denmark was heavily dependent on imported fossil fuels.

The oil crisis of the 1970s was a wake-up call for Denmark that fossil fuel dependency was a significant concern to national security and critical to the country's future economic development. In response, the government and the Danish consultancy company Ramboll developed a national heat map and heat plan that became the foundation for the next 20 - 30 years of long-term planning, investment, and implementation of DH systems in Denmark. Based on the heat map and financial analysis, the government made new DH laws, taxation measures and regulations to mandate the utilization of waste heat from industrial coal and oil-fired power plants for DH networks in the main cities in Denmark.

Simultaneously with the new regulations, it became mandatory for households close to a DH system to connect to it (known as mandatory connections). Mandatory connections helped to accelerate the adoption of district energy in municipalities across Denmark and reduce the dependency on imported oil. Provisions for mandatory connections were removed from policy in the 2000's. To receive approval to develop a district energy system in a new area and in lieu of mandatory connections, at least 60% of customers are required to commit to a district energy connection once the system is fully built.

Aside from an increase in renewable electricity production and adoption of district energy, a key pillar to Denmark's long-term transition to a low carbon and green economy included converting power plants from fossil fuels to plants that leverage low-carbon alternatives such as biomass, municipal waste incineration, or renewable natural gas (RNG) [4].

SEVERAL ACTS, SUCH AS THE ELECTRICITY SUPPLY ACT, NATURAL GAS SUPPLY ACT AND HEAT SUPPLY ACT, ACCELERATED THE GREEN TRANSITION ACROSS DENMARK.

The Electricity Supply Act included regulations for power production and prices to ensure the integration of electricity supply into the country's energy supply. Energy taxes were imposed on oil and electricity through the Electricity Supply Act, primarily for fiscal policy reasons and to enhance energy savings.

The Natural Gas Supply Act was then enacted to ensure Denmark's natural gas supply was organized and implemented in accordance with supply security, socioeconomics, environment and consumer protection.

The Heat Supply Act introduced municipal heat planning, where directives were sent to all municipalities and regions. The directives included guidelines for municipalities to navigate selecting the most socio-economic projects. Another condition of the Heat Supply Act was that waste heat from power plants must be used for district heating. At the same time, the Danish government and municipalities nationwide provided public loan options with favourable low interest rates to energy producers. These economic incentives and sweeping CO2 prices proved to be instrumental in reducing risks associated with district energy projects. Investor security is provided through coordinated zoning efforts and provisions to municipalities on connection rules for heat consumers. The municipalities also offer loan guarantees to de-risk investments and other associated risks further. Through the Heat Supply Act, consumer protection was also established through price regulations and non-profit tariffs.

HISTORICAL DEVELOPMENT IN DENMARK

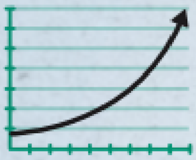
THE NEXT TWO PAGES PROVIDE A DETAILED OVERVIEW OF THE POLITICAL HISTORY OF DENMARK'S TRANSITION TO DE AND RENEWABLE FUEL SOURCES FROM THE STATE OF GREEN'S WHITE PAPER TITLED "DISTRICT ENERGY".

IN SUMMARY, THE MAIN DRIVERS OF THE DANISH TRANSITION TO WIDESPREAD ADOPTION OF RENEWABLE FUEL SOURCES, IMPLEMENTATION OF DISTRICT ENERGY SYSTEMS AND CONSTRUCTION OF ENERGY-EFFICIENT BUILDINGS ARE EARMARKED BY THE FOLLOWING SIX MILESTONES:

1970'S	REDUCE THE DEPENDENCY OF IMPORTED OIL FROM UNSTABLE AREAS IN THE WORLD, CHANGE TO COAL.
1980'S	REDUCE ENVIRONMENTAL IMPACT FROM POWER PRODUCTION, INTRODUCING GAS IN THE ELECTRICITY AND HEATING PRODUCTION.
1990'S	INTRODUCTION OF RENEWABLE ENERGY SOURCES IN THE ELECTRICITY AND HEATING SYSTEMS. EXPANDING DISTRICT HEATING NETWORKS IN LARGE CITIES.
2000'S	USE OF SURPLUS HEAT FROM MANY DIFFERENT HEATING SOURCES INTO THE DISTRICT HEATING SYSTEM, PHASING OUT OF COAL.
2010'S	DECARBONIZATION OF ELECTRICITY AND HEAT PRODUCTION, INTRODUCING HEATING FROM DATACENTERS INTO THE HEATING NETWORK.
2020'S	FOCUS ON EITHER DISTRICT HEATING NETWORK IN CITIES AND TOWNS, FOCUS ON HEAT PUMPS IN REMOTE AND RURAL AREAS.

HISTORICAL OVERVIEW OF DISTRICT ENERGY IN DENMARK

FOCUS ON ENERGY EFFICIENCY AND SECURITY OF SUPPLY

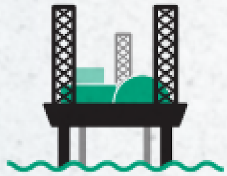


1973-74. The high energy prices caused by the international energy crisis increased the Danish focus on fuel independence and motivated improvements in energy efficiency.

1976-79. Denmark's first overall energy plan lays the basis for a long-term energy policy and the Danish Energy Agency is established. The first law on heat supply starts a new era in public heat planning which still exists today.

1981-82. National heat planning takes place throughout the country. The heat plans include "zoning" with the purpose of establishing efficient, low-emission energy systems.

INCREASED FOCUS ON DOMESTIC FUELS



1984. The Danish North Sea natural gas production begins. The Ministry of Energy directs power plants to establish natural gas installations.

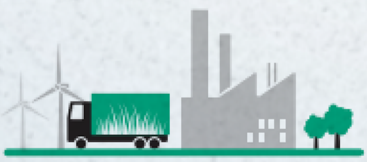
1985-86. Parliamentary decision on public energy planning without nuclear power. Coal was excluded from heat planning. Energy taxes are increased due to a drop in oil prices. The co-generation agreement emphasizes small-scale CHP plants as a major energy policy priority.

1990. Political agreement on increased use of both natural gas-fired CHPs and biomass for heat in district heating. Furthermore, the agreement increased installation of wind power.

CHANGE FROM NATIONAL PLANNING TO PROJECT APPROACH

1990. Revision to law on heat supply introduces a new planning system. Planning directives and guidelines for fuel choice and CHP is provided to all local authorities/municipalities.

1992. A range of subsidies were introduced in order to support energy savings, CHP and renewable energy sources.



1993-2000. Political agreement on the use of biomass in power production. Revision to law on heat supply. A political majority in the Danish Parliament decides to improve conditions for 250 small and medium-sized CHP plants outside the major cities.

THE KEY TO SUCCESS IN DISTRICT ENERGY

A peek into four decades of lessons learned in Denmark

District heating continues to be a cornerstone of the Danish green energy model. For decades, it has provided us with an efficient way to use our surplus heat. Moreover, in the future it will be a key element supporting the integration of wind energy.

Kristoffer Böttzauw, Director General, Danish Energy Agency

District heating - a cornerstone in Denmark's green transition
The very first combined heat and power plant in Denmark was built in 1903. It was a waste incineration plant, which made it possible to handle waste and provide electricity and heat to a nearby hospital, thereby delivering two services simultaneously.

During the 1920s and 1930s, a collective district heating system was developed, based on excess heat from local electricity production. From here on, district heating from combined heat and power (CHP) expanded, and by the 1970s, around 30% of all homes were heated by district heating systems.

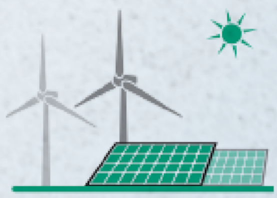
Decreasing energy dependency and consumer costs
The energy crisis in 1973/74 made it evident that saving energy was critical both to decrease the dependency of imported fuels and to reduce consumer heating costs. Therefore, a decision was made to expand the fuel-efficient CHP systems to a number of cities in Denmark.

First heat supply law in 1979
Prior to 1979 there was no law regulating the heat supply in Denmark. Most heat consumers had small oil-fired boilers or other forms of individual heating. In order to fulfil its policy goals, Denmark passed its first heat supply law in 1979. The law contained regulations regarding the form and content of heat planning in Denmark and marked the beginning of a new era in public heat planning, which still exists today.

High energy efficiency is one of the results of long-term planning
Today, 63 per cent of all Danish residential homes are connected to district heating for space heating and domestic hot water. When producing heat and power using CHP, the overall energy efficiency is significantly higher than when producing heat and power separately. A CHP plant may have a total efficiency (combined heat and power) of 85-90 per cent resulting in an overall fuel saving of approximately 30 per cent, compared to separate production of heat and electricity. District heating and CHP have been – and continue to be – a key ingredient to Denmark's green transition.

Flexibility to develop and continuously support different policy goals
District heating ensures that Denmark has a sound and reliable heating supply. It also greatly supports Denmark in maintaining a sustainable energy sector and fulfilling its long-term energy policy targets. Looking ahead, district energy will remain a key element of the energy system in Denmark. By 2030, it is expected that wind energy will cover 100 per cent of the Danish electricity consumption. This has created heightened focus on flexible district energy systems that will support the integration of wind power into the energy system. Therefore, district energy not only contributes to achieving Denmark's climate goals but also plays a major role in balancing the future energy system.

FOCUS ON CLIMATE, RENEWABLE ENERGY AND ENERGY EFFICIENCY



2012. Broad political agreement for Danish energy policy 2012-2020. The agreement included initiatives within energy efficiency, renewable energy and the energy system. The agreement was renewed in 2018 to cover the period 2020-2030.

2030. Ambitious political target of a 70 per cent reduction of CO_2-emissions by 2030 in relation to 1990 levels. It is expected that 100 per cent of Danish district energy will be supplied by green sources by 2030.

2050. Political agreement from 2012 sets the ambition for a Denmark independent of fossil fuels by 2050.

2. HISTORY

2.1 GENERATIONS OF DH

The first generation of DH systems utilized steam with supply temperatures of approximately 148˚C (300˚F) or higher. In steam systems, there are safety concerns involving high temperatures and high-pressure steam and the possibility of explosions in poorly maintained pipes resulting in damage to roads, houses, and injuries to anyone near the blast. Steam systems use gas-fired boilers where the system uses excess fuel than required to meet heating requirements, resulting in decreased energy efficiency. Steam systems do not require pumps as the high-pressure steam naturally flows through the system. Pumps are, however, necessary for condensing in 1st generation systems.

The second generation of DH systems utilized hot water with supply temperatures of between 90 and 150˚C (194 – 300˚F). In systems where the hot water supply temperature is required to be higher than the boiling temperature (100˚C (212˚F)) the DH hot water system must be pressurized to avoid steam production. Due to the lower supply temperature compared to steam systems, hot water systems require less fuel to operate, thus decreasing carbon emissions by at least 30% and increasing efficiency by up to 50% compared to steam systems [5]. Hot water systems are safer to operate when compared to steam systems. Hot water systems are less expensive to install as they can use smaller pipes and can be placed at shallow ground levels since there are minimal safety risks of leaking or explosions as opposed to steam systems. Additionally, the operation of a water-based DH system is similar to potable water systems and requires minimal labour when starting and closing the system for the heating season. Wear and replacement of the equipment in a water-based DH system are less frequent and costly than in steam systems, resulting in less O&M in the higher generation systems.

The third and fourth generations of DH systems are similar to the second generation as they also use water-based supply and return distribution systems. The main differences and advantages of 3rd- and 4th-generation DH systems are the water supply and return temperatures in the systems, which in turn means different generation equipment is required. Lower operating temperatures result in the following benefits:

- Higher energy efficiency as less energy is needed to create lower temperatures [6]
- Lower fuel consumption and, as a result, decreased GHG emissions
- Less heat loss as the distribution temperature is closer to the surrounding environment
- Higher percentage of renewable energy sources can be utilized for DE production, including low-grade waste heat

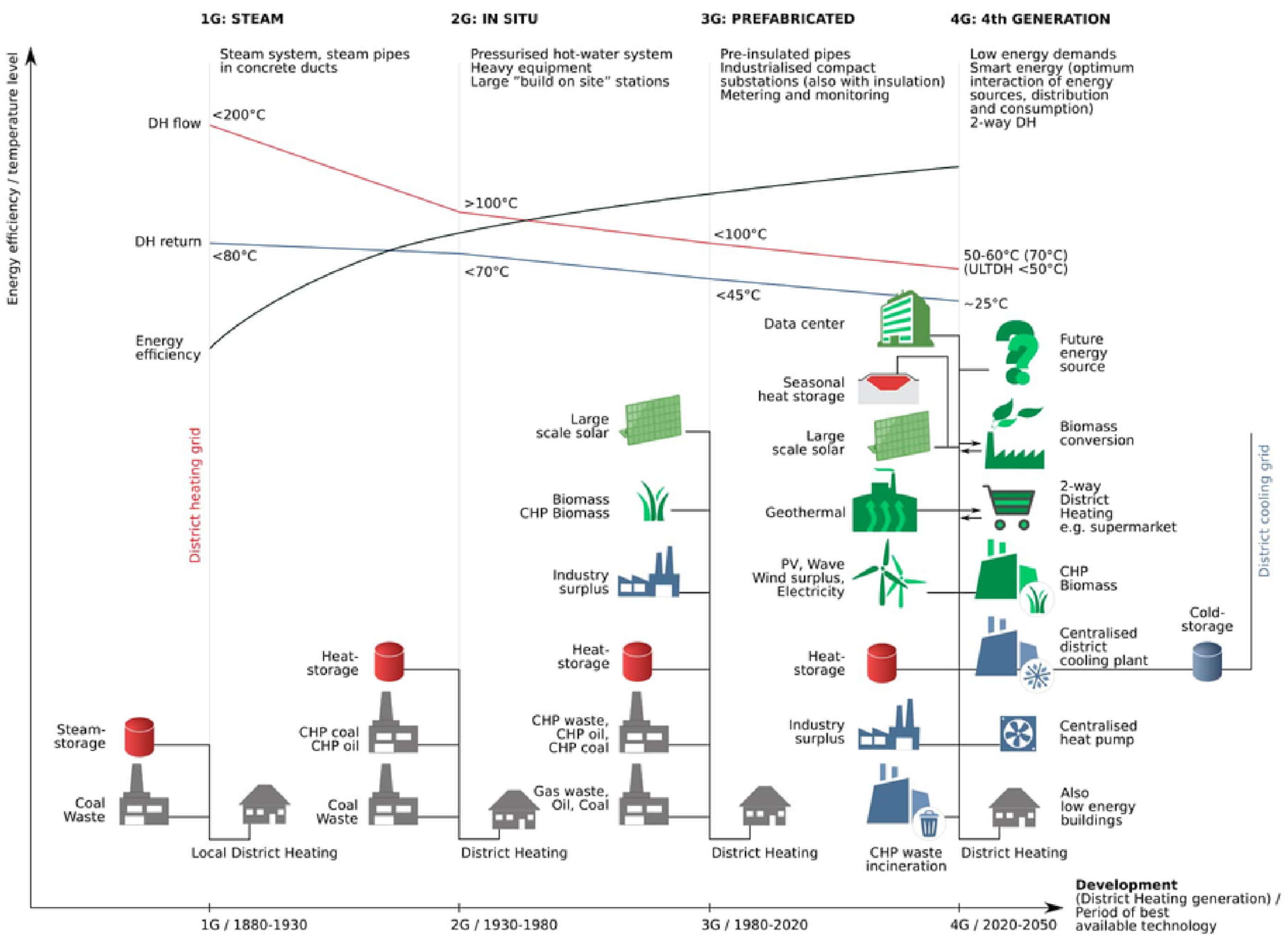
2. HISTORY

TYPICAL DE SUPPLY TEMPERATURES ARE BELOW FOR EACH GENERATION OF DH SYSTEMS:

Third-generation DE systems have a supply temperature below 100˚C (212˚F).

Fourth-generation DE systems operate with supply temperatures below 70˚C (158˚F).

Fifth-generation systems (considered ultra-low or ULTDH) operate below 50˚C (122˚F), are not discussed as these systems are relatively novel and still largely being researched.



3. ADVANTAGES OF DISTRICT ENERGY

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3. ADVANTAGES OF DISTRICT ENERGY

GREEN GROWTH

- Investment opportunities that offer not only stable and long-term returns but are also aligned with green growth principles.
- Attract both local and international investors to foster a green energy ecosystem.
- Foster long-term job creation locally and internationally by actively participating in developing and implementing DE infrastructure.
- Drive the development of a resilient domestic energy economy by prioritizing localized production and distribution of sustainable fuels.
- Are often scalable and adaptable, making it easier to accommodate changes in energy demand or integrate new technologies over time further driving green growth.

FLEXIBILITY IN FUEL TYPES

- DE systems allow for various fuel types, providing scale and flexibility based on available resources, regulations, and cost.
- An increased utilization of local resources further increases the security of heat supply and flexibility, which can result in less dependency on fossil fuels.
- DE systems can use various renewable energy options for heating and cooling and CHP, including geothermal, waste-to-energy, biomass, waste heat recovered from sewage plants, solar thermal, wind or wave heat pumps, industrial surplus heat from data centres, and cooling water from oceans and lakes.
- Re-use of waste product. For example, Denmark helps create a circular economy where fly ash from power plants are used as fertilizer and to enhance concrete mixes.

HEALTH AND AIR QUALITY IMPROVEMENT

- A DE system reduces carbon emissions and other GHGs, thus improving air quality.
- Health and safety levels in dense urban areas are significantly increased by implementing a fourth-generation DE system compared to a steam DE system.

IMPROVES SPACE UTILIZATION & REDUCES MAINTENANCE COST

- Can contribute to more efficient land use by consolidating energy infrastructure in urban areas, freeing up space for other purposes.
- Space needed for heating and cooling equipment is significantly reduced with a DE system.
- Maintenance and life cycle renewals of significant heating and cooling equipment are eliminated for building owners because these are shifted from the building owner to the DE network.
- Reliability is improved at the building by using DE because the building owner shifts the responsibility of heating and cooling to the DE network, which typically hold levels of redundancy.

3. ADVANTAGES OF DISTRICT ENERGY

COST EFFICIENCY

- Large-scale integration of renewable energy sources has lower investment costs than individual energy production units (A/C units or building boilers).
- Reliable prices over the year for the consumer without sudden increases based on operation and maintenance.
- DE systems provide the opportunity to take advantage of market forces driving price changes on different types of fuels.
- Allows centralized, long-term planning and investment, reducing uncertainties associated with individual building-level systems.

ENERGY EFFICIENCY IMPROVEMENTS

- Opportunity to reuse excess heat from electricity production or industrial processes.
- Increase energy efficiency by at least 30% by eliminating individual energy production units (A/C units or building boilers) [7].
- DE systems typically reduce fuel consumption for heating and cooling by reducing energy loss, co-producing heat and electricity, utilizing thermal storage, and assisting with peak load demand by using energy more efficiently.
- Can be integrated with smart technologies for better control, monitoring, and optimization. This integration can lead to more efficient energy use and improved system performance.

CLIMATE CHANGE RESILIENCY

- Fuel flexibility, in addition to redundancy, in a DE system increases both the security of supply and production efficiency since backup equipment and fuel sources exist in a DE system.
- Fuel flexibility allows for the adaptability necessary for climate change resiliency over time.
- DE systems often have redundancy and backup capabilities, enhancing reliability and resilience. In case of a failure in one part of the system, alternative sources or pathways can be used to maintain the energy supply.
- Centralized systems are often better equipped to handle disruptions or emergencies, contributing to the overall resilience of the energy infrastructure.

3. ADVANTAGES OF DISTRICT ENERGY

3.1 ELEMENTS OF A SUCCESSFUL DISTRICT ENERGY SYSTEM

DEVELOPING A DE SYSTEM

Planning

Successful DE systems are able to be developed with effective initial master planning. Planning for DE systems includes demand mapping (heat, cooling energy), investment and financial system scaling, and implementation plans, which are critical to developing DE systems. So is developing a long-term renovation plan. Transparent pricing, regulated rate structure, and all customers paying equally should be reflected in the project business case and long-term planning.

Experienced Consultants & Stakeholders

DE systems need experienced, skilled consultants, investors, contractors, site supervisors, equipment suppliers, and master planners who have worked on successful DE projects. Ensuring all relevant stakeholders are involved throughout development helps ensure a successful project.

Training

As DE expertise varies in North America, the stakeholders involved in the implementation and development of the project should be adequately trained and educated. When looking specifically at implementation, proper installation and quality control are critical to the long-term success of a DE system.

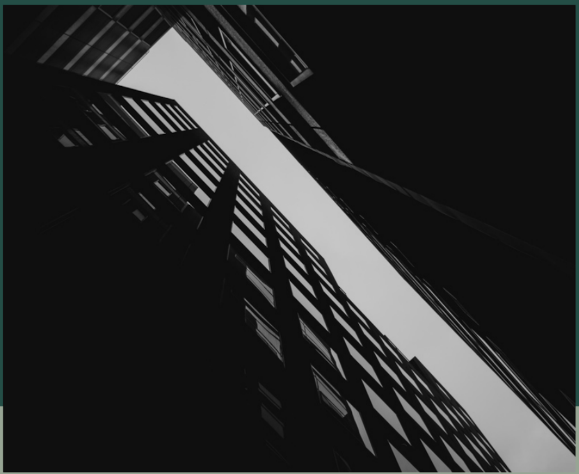
ESTABLISHED DE SYSTEM

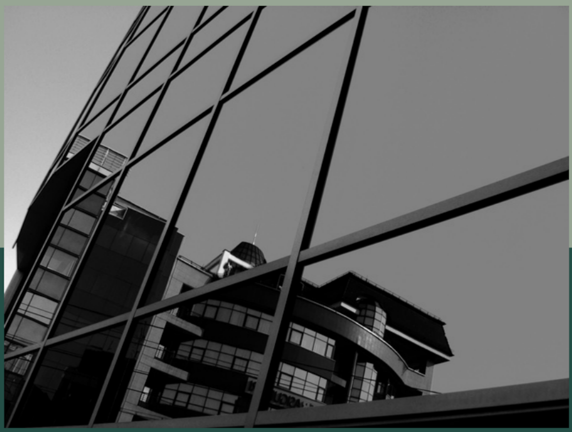
Overall Performance

If designed, implemented, and operated correctly, the most energy-efficient and fuel-flexible DE system is a hot water-based DH system and a cold water-based DC system. These systems last 30 - 50 years with minimum maintenance throughout their lifetime.

Management of the system

To ensure successful long-term performance and efficiency for a DE system throughout its lifetime, professional management with experiences from operating similar systems is necessary, as decisions based on lifecycle assessments are crucial for long-term financial and operational success.





QUALITY CONTROL

Site Supervision

Frequent site supervision from an experienced and adequately trained supervisor is crucial to a successful DE system. Many operational and financial failures in DE projects are due to the need for more site supervision and inexperienced site supervision during implementation.

Documentation

Quality control documentation, consistent revision, and updating of the system plans are crucial to successful and effective site supervision and future maintenance of the systems. The DE system must be implemented based on the most recent revisions and updates, especially in the leak detection system. Suppose pipe routing/trench changes occur during implementation (to avoid unforeseen obstacles in the ground). In that case, the new local pipe design and stress calculations must be updated, verified, and updated in documents and drawings.

OPERATION & MAINTENANCE (O&M)

DE System Operation

To make sure an implemented DE system performs successfully, energy metering and consistent data collection from the production, distribution, and end consumers are necessary. This data collection and metering will also monitor the energy consumption of the connected buildings.

DE companies are increasingly incorporating digitization to remotely read heat meters throughout a DE network. Access to remote meters allows operators to optimize operations and monitor performance to ensure cost-effective operations while maximizing efficiency. See Section 6 for an example of digitalization in practice in an active Danish DE system.

DE System Maintenance

A functional and well-maintained leak detection system is crucial for the long-term performance of a DE system. In the EN253 pre-insulated pipe systems, the pipes are delivered with leak detection wires integrated into the pipes. These leak detection wires only need to be interconnected when welding together the pipe lengths.

Maintenance of the supply and return water quality is necessary throughout the lifetime of a DE system. If the specified water quality parameters are constantly maintained, the lifetime of thin-walled EN253 steel pipes (in Denmark) can be over 30 years [8].

3. ADVANTAGES OF DISTRICT ENERGY

3.2 ENERGY SOURCES

The following table provides an overview of the possible energy sources that could be utilized by a district energy system and highlights some advantages of each. The information below is provided for information purposes only and should not be relied upon for decisions, design or similar efforts. A qualified professional should be engaged when selecting and evaluating technologies and energy sources for a specific system or geographical area.

TECHNOLOGY	SOURCE	ADVANTAGE	ESTIMATED HEATING OUTPOUT PER PRODUCTION UNIT/PLANT
BIOENERGY	• Wood pellet and chips • Straw • Garden waste • Agricultural waste • Municipal waste	• Heating and CHP • Utilizes local resources and waste products that would otherwise be sent to landfills or release methane gasses from degradation. Can replace carbon releasing energy production sources used for heating and cooling	150kW - 25MW
INDUSTRIAL WASTE HEAT	• Factories • Steel production plants • Heavy energy intense production facilities • Cement plants • Food processing plants • Manufacturing plants, • Combustion engines • Cooling towers	• Heating, cooling and electricity production • Utilizes waste heat from industrial processes providing cheap or free fuel for heating and cooling purposes. Can replace carbon releasing energy production sources used for heating and cooling	50MW – 350MW
HYBRID SYSTEMS & LARGE SCALE HEAT PUMPS	• Water-source heat pumps • Air-source heat pumps	• Utilize energy from various sources to provide heating or cooling • Heat pumps can be used to increased efficiency of combustion equipment through pre-heating water • Capable of providing water at high temperatures (~100C) • Systems capable of providing simultaneous heating and cooling	1MW – 30MW

TECHNOLOGY	SOURCE	ADVANTAGE	ESTIMATED HEATING OUTPOUT PER PRODUCTION UNIT/PLANT
GEOTHERMAL	• Ground-source heat pumps	• Heating, cooling, electricity production • Provides long term energy infrastructure with a small footprint. Can replace carbon releasing energy production sources used for heating and cooling	1MW – 80MW
SOLAR THERMAL **SOLAR POWER PLANTS**	• Solar energy	• Heating and electricity production • Utilizing the heat from the sun and providing a variety of scale: panels on a single-family house roof to large scale solar farms. Can replace carbon releasing energy production sources used for heating and cooling	500kW – 50MW
WATER	• Wastewater treatment plants (sewage and plant) • Lakes/ oceans/ seas	• Heating and cooling • Utilizing existing hot and cold temperatures in nearby large bodies of water and wastewater treatment plants. Providing cheap or free fuel for heating and cooling purposes. Can replace carbon releasing energy production sources used for heating and cooling	1 MW – 20MW
ELECTRIFICATION OF DH AND DC SYSTEMS THROUGH WIND	• Wind	• CHP • DE systems can be used to store wind energy when there is a surplus of wind energy. Wind energy can power electric heat pumps that can produce both district heating and district cooling.	500kW – 30MW
COMBUSTION	• Oil, gas, coal	• Available in almost all parts of the US and Canada from big cities to rural areas.	2MW – 500MW

3. ADVANTAGES OF DISTRICT ENERGY

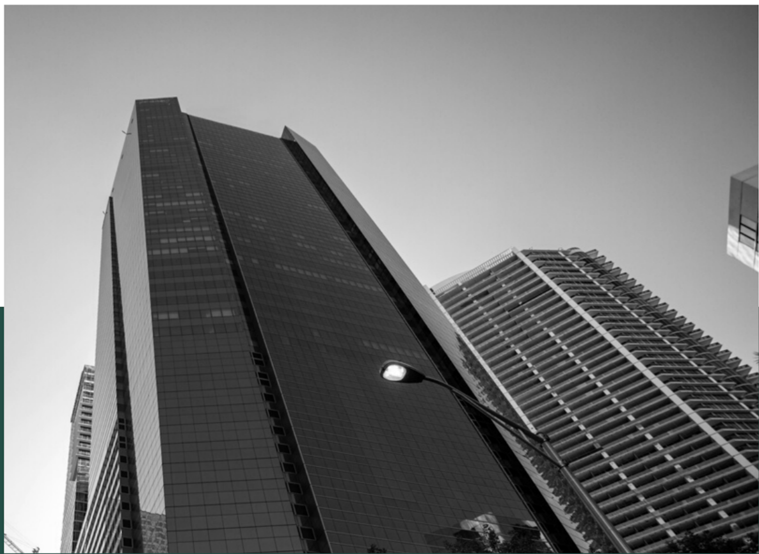
3.3 NORTH AMERICA MARKET SNAPSHOT

Canada has ~150 district energy systems, including 21 CHP systems, which in total serve over two million people in over 40 communities. The Canadian district energy market is projected to grow at a CAGR of 5.2% from 2020 to 2027, reaching USD 1.2 billion by 2027. The growth is attributed to increasing urbanization, rising environmental awareness, and growing investment in infrastructure development.

At the time of publication, Canada's installed district energy capacity is 4,604MWth of heating and 1,144MWth of cooling according to the Canada Energy and Emissions Data Centre. Most existing projects are in downtown centres, whereas 85% of the upcoming projects in Canada are also in downtown centres. The remaining 15% of the upcoming projects are located in universities and colleges across Canada.

The U.S. district energy market is expected to grow at a compound annual growth rate (CAGR) of 4.7% from 2020 to 2027, reaching USD 8.9 billion by 2027. The growth is driven by increasing demand for energy-efficient and cost-effective heating and cooling solutions, rising adoption of renewable energy sources, and supportive government policies and incentives.

The export of Danish district heating technology in 2022 was estimated to be DKK 5.6 billion (~US$800M) worldwide. The U.S. is the second largest export market for Danish district heating technology, which imports ~8% of the Danish district heating technology or DKK 4.5 million ((~US$650,000), annually. The total import value of Danish district heating technology in the United States and Canada is expected to continue to increase, especially given the accelerated adoption of district energy across North America.



4. DELIVERING SUCCESSFUL DISTRICT ENERGY SYSTEMS

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4. DELIVERING SUCCESSFUL DISTRICT ENERGY SYSTEMS

DISTRICT ENERGY, WHILE A PROMISING SOLUTION, CAN BE CONFRONTED WITH A RANGE OF FORMIDABLE CHALLENGES. THESE SYSTEMS OFFER ENVIRONMENTAL AND ECONOMIC BENEFITS BUT FACE COMPLEX TECHNICAL, FINANCIAL, REGULATORY, AND SOCIAL HURDLES. THIS SECTION EXPLORES THE MULTIFACETED CHALLENGES THAT MUST BE ADDRESSED TO UNLOCK THE POTENTIAL OF DISTRICT ENERGY SYSTEMS, STRENGTHEN THE ENERGY MIX AND REALIZE A SUSTAINABLE ENERGY FUTURE.

4.1 UPFRONT COSTS & PAYBACK

Given the scale of DE systems, they typically have high upfront capital costs due to the scale and technical requirements of the infrastructure. These elements include distribution and connection pipes, thermal plants and storage, and possible connections to the existing electricity network in the case of CHP plants.

A tool being utilized to de-risk new DE projects is public-private partnerships, where public money is provided at locked-in interest rates to help de-risk investments in large infrastructure projects. Public finances are meant to encourage private investments given the financial security provided and mitigation of initial risks. Innovative financing models are also becoming increasingly prevalent to support the optimization of existing DE systems, such as the engagement of an Energy Saving Company (ESCO). An ESCO plans and executes the optimization of a DE project where the cost is financed through the achieved energy savings.

Usually, the first building to connect to the grid is the furthest away from the distribution centre. Connecting additional buildings or facilities will depend on the progression of the market and site; this creates the “first pipe conundrum”, where the first building connection takes all the payback risk of the DE system as future building connections will bring the price down through economies of scale.

The payback period for the investment of a DE system is often above 8-10 years, which does not meet the payback standard for many North American development projects.

However, payback periods should not be the only consideration when evaluating the business case of DE projects. Completing a life-cycle analysis of a DE system is important to understand the long-term savings and benefits of this system, such as energy and maintenance savings.

4. DELIVERING SUCCESSFUL DISTRICT ENERGY SYSTEMS

4.2 COMPLEX PROJECT PROCESS

Developing DE systems involves coordinating several stakeholders, including owners of future building connections, residents, public and private bodies, utilities, consultants, contractors and developers. Early engagement with critical stakeholders across sectors is essential to delivering a successful DE project.

4.3 REGULATORY & MARKET

In North America, local governments generally possess less regulative authority than Europe, restricting the ability to mandate heat network connections. Additionally, local governments only sometimes have a stake in utilities whose role is essential in developing DE systems. Political priorities often shift, making long-term infrastructure projects more challenging to create.

The price of natural gas in North America is currently very low, making it difficult to compete with other sources, including renewables. However, DE systems can utilize natural gas until renewable fuel costs are competitive.

4.5 PUBLIC AWARENESS & POLICIES

Limited understanding and awareness of the long-term benefits of DE systems can slow down or even stop the planning of DE systems. North American development stakeholders are often more comfortable with conventional solutions and are averse to trying more innovative solutions regardless of the long-term benefits and proven case studies.

Local governments often need access to consultants who can perform screening and feasibility analyses to assess the potential of a DE system. Different strategies can be employed to strengthen public awareness, and local stakeholder involvement early in the project has shown itself to be critical to the acceptance and success of DE projects in Denmark.

Many existing building policies and rating systems focus on individual building operation efficiencies rather than considering system efficiency that occurs in a connected network. Many sustainable building programs and certifications should consider decentralized thermal energy production as a pathway to decarbonize the built environment.

5. BEST PRACTICES IN DISTRICT ENERGY

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5. BEST PRACTICES IN DISTRICT ENERGY

5.1 ODENSE WASTE HEAT DE – FACEBOOK DATA CENTER

- Area covered: 11,000 mostly residential units.
- Type of system: DH, DC Pre-insulated DN253 twin and single pipes (integrated leak detection).
- DE process: The waste heat from cooling the Facebook data center is processed through the DE system, which is then sent to the residential units. The cooling produced in the DE system is returned to Facebook as district cooling to cool the data center.
- Type of fuel: Electric (local grid) driven large-scale industrial heat pumps (in total approx. 45 MW installed heating capacity).
- Buildings serviced: Single family housing and residential apartments.
- Ownership model: Local public owned heating not for profit utility.
- Regulatory support: Reduced taxation on energy produced from waste heat.

5.2 AARHUS CITY DE SYSTEM

- Area covered: City of Aarhus and surrounding municipalities, approx. 300,000 people, 60,000 customers, 2,250 km / 1,400 miles of distribution pipes.
- Type of system: DH, CHP, Pre-insulated DN253 twin and single pipes (integrated leak detection).
- DE process: Electricity and heating is co-produced from the incineration of municipal non-recyclable waste and biomass and sent to a large storage before distribution to the serviced area. Additionally, heat is produced from seawater going through heat pumps, and a minor quantity is delivered from waste heat from industries within Aarhus.
- Type of fuel: Biomass (excess straw from agriculture) and non-recyclable waste, industrial waste heat and seawater.
- Emissions: On track in meeting the goal of carbon neutrality by 2030.
- Buildings serviced: Commercial, multifamily, and single-family homes.
- Ownership model: Owned entirely by the municipality of Aarhus - not for profit DE system.
- Regulatory support since 1970s: Mandatory connection to DH system through government policies.

5. BEST PRACTICES IN DISTRICT ENERGY

5.3 SHERIDAN COLLEGE STEAM TO HOT WATER CONVERSION

- Area covered (Brampton campus): 700,050 sqf of institutional buildings with capabilities of future expansion to neighboring communities. 3.5 km of distributed pipe.
- Area covered (Oakville campus): 810,000 sqf of institutional buildings with capabilities of future expansion to neighboring communities. 3.5 km of distributed pipe.
- Type of system: DH, DC, CPH. Pre-insulated DN253 twin and single pipes (integrated leak detection).
- DE process (Brampton campus and intended design for Oakville campus): Electricity and heating are co-produced from combined heat and power engines. Additionally, heating used by absorption chillers to produce cooling in the summer months.
- Type of generation: Generation 4.
- Type of fuel: Natural gas.
- Buildings serviced: Currently 7 buildings with long term plan of 17 across both campuses.
- Ownership model: Owned and maintained by Sheridan College.
- Operating efficiency: 20% reduction in natural gas.
- Additional notes (Brampton & Oakville Campus): Use of prefabricated energy transfer stations reduce installation time and increase energy efficiency through custom production for the specific building.
- Emissions targets: Converting from steam to hot water has contributed to Sheridan achieving its 50% carbon reduction target.

6. STATE OF GREEN CASE STUDIES

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6. STATE OF GREEN

The following pages include a selection of case studies from State of Green and provide an overview DE use cases in Denmark and Europe.

State of Green is a public-private partnership operating the official green brand for Denmark. They provide a platform for the world to learn about the solutions and competences of Danish businesses, organisations, cities and institutions within energy, climate adaptation and environment.

DISTRICT COOLING REDUCES CO2 EMISSIONS IN CENTRAL COPENHAGEN

Increasing demand for cooling

There is an increasing demand for air conditioning and cooling in Copenhagen as in many other cities around the world. The Copenhagen utility company, HOFOR, has built a district cooling system, which consists of a distribution net and two cooling plants. The district cooling system uses seawater to chill down the water supplied to the customers. The system supplies commercial buildings such as banks, department stores, and offices as well as cooling for data centres and other processes all year round.

Therefore, HOFOR can supply the increased demand for cooling in Copenhagen and help reduce CO2 emissions by up to 30,000 tonnes each year. The cooling system now supplies the centre of Copenhagen with cold water, and the pipe system is expanded in order to supply more customers in the future. HOFOR's district cooling activities are the biggest of their kind in Denmark. The first cooling plant was opened in 2010, the second plant in 2013, and the system is still under expansion. From 2015 until 2020, it is the ambition to expand district cooling further by doubling the amount of customers and thereby contribute further to Copenhagen's target to become CO2- neutral in 2025.

Cooling is produced centrally in three different ways:

In winter months, the chilled water to the customers is produced by using seawater. The seawater is pumped into the cooling plant through a pipe from the harbour. The seawater temperature is a maximum of 6 °C, when it is used directly to cool down the water for the customers. This is known as zero-carbon cooling. However, a small amount of electricity is used when pumping seawater into the cooling plant. In summer months, when the seawater is not sufficiently cold, energy must be used to chill down the water. Seawater is used to increase the efficiency of the other installations. Using seawater to remove the heat from the machines reduces electricity consumption by up to 70% compared to a local compressor.

Also during summer months, waste heat from the power plants is used for cooling. This method is known as absorption cooling and is only used when there is waste heat from the power plants available. The absorber minimises the CO2-emission.

Author: Henrik Lorentsen Bøgeskov, Head of District Cooling, HOFOR

TOOLS FROM KAMSTRUP ALLOWED A LOCAL UTILITY TO OPTIMISE ITS OPERATIONS

When Assens District Heating decided to invest in intelligent heat meters and a remotely read network solution back in 2013, digitalisation was still a buzzword to many, and no one knew its true potential. Nevertheless, the utility had a clear expectation that more frequent meter data would provide enhanced opportunities for optimisation.

Data-driven operations optimisation

The first phase of utilising the large amounts of data was optimisation of the distribution network. Specifically, the utility has been able to lower the forward temperature significantly. Previously, it was determined based on the end users who lived the furthest away, resulting in a higher temperature than necessary. Today, it is optimised based on what happens in the network. Once all the meters were up and running, the utility faced a wall of data. The tools provided from Kamstrup suddenly allowed it to see – on an hourly basis – the exact temperature throughout the network. Based on continuous digitalisation of the operations, the utility has been able to lower the forward temperature by 6-8 degrees Celsius. The utility has also been able to remove its more than 100 bypasses around the network.

Large savings achieved through digitalisation

By optimising the network operations,Assens District Heating has saved 2,500-3,000 MWh – approximately 2.5 percent– and reduced pipeline losses by 12 per centover the last few years. The data has helped understand the hundreds of kilometres of pipes and what actually happens when, for instance, the temperature is lowered. Even employees with decade's worth of experience have previously not had a full overview of the outcomes when making those kind of changes. The utility expects to gain even more when they commence the next phase soon. Savings to-date have been generated by looking at the volume and temperature of the water pumped out. Only now is the utility beginning to look at individual buildings, end users with poor energy behaviour and inefficient installations.

Frequent data is also used to assess the actual need for renovating the district heating pipes. Previously, the condition of the distribution network was estimated based on factors such as age or water loss. Now that meter data from the network is combined with innovative analytics, it allows continuous monitoring of the capacity and load so that investments in network maintenance can be optimised.

MUNICIPALITY IN TRANSITION TO LOW-TEMPERATURE DISTRICT HEATING

Albertslund District Heating Company was established in 1964, and the district heating supply area increased in line with the development of the city. Initially, the district heating network was established for operation with a supply temperature of 110 °C. Over the years, the temperature has been lowered, and today the system operates with a flow temperature of approx. 90 °C.

4th generation

As part of Albertslund municipality's vision for the heat and electricity supply to be CO_2-neutral by 2020, a new low-temperature 4th generation district heating system, where the supply temperature is lowered from 90 to 55 °C, is being established. This allows for more efficient use of the existing heat generation plant and lowers heat losses from pipework, thus helping Albertslund achieve its goal of a CO_2-neutral heat supply. Based on the success of the first phase, Albertslund has recently taken the bold decision to convert the entire town, approximately 30,000 inhabitants, to low temperature district heating before 2026.

Challenges

While it is relatively easy to supply new apartments with low-temperature district heating, older apartments are generally poorly insulated and require a high flow temperature to give an adequate comfort level. Albertslund Municipality is, therefore, instituting a renovation program which switches apartments to low-temperature district heating and thereby increases their energy efficiency.

The distribution system

Apartments are connected in phases in line with the renovation plan and the termination of the high temperature distribution system. The low temperature circuit is supplied via the return from the 'old' district heating system, which is mixed to 55 °C through a shunt valve.

The apartment system

New low temperature instantaneous water heaters are installed in the apartments, which supply domestic hot water at 45 °C on the consumer side. Legionella is controlled by design according to the German rule DVGW W55, which requires that only a very small amount of water is held in the heat exchanger and hot water system at any time. After refurbishment, the apartments are supplied with space heating via underfloor heating and radiators. The overall supply temperature from the district heating system is 55 °C and the return temperature from the user will be around 30 °C.

7. APPENDIX

EXAMPLE OF DE BUSINESS CASE

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CITY OF PITTSBURGH

INTRODUCTION

Representatives from the Danish District Energy Advisory (DDEA) of the Danish Ministry of Foreign Affairs and the City of Pittsburgh have prepared a comparative business case for energy options for DE consumers (heat only) in Pittsburgh, together with a business case on energy production from Pittsburgh Allegheny County Thermal (PACT), one of the City's District Energy steam suppliers. Pittsburgh is shifting its focus towards climate change and investing in sustainable green energy infrastructure. The City of Pittsburgh is invested in involving key stakeholders in this transition as well as educating residents on a wide variety of energy options. Pittsburgh's ultimate goal is "to ensure economically viable and low-greenhouse gas-emitting heating and cooling to the City of Pittsburgh."

RESIDENTIAL BUSINESS CASE

State-wide, Pennsylvania households consume natural gas at a rate that is 8% higher than the national average. This is likely due to cold winters that require an excess amount of heating. Old homes in the state, and in Pittsburgh, present additional heating and cooling challenges; they lack efficiency resulting in high heating costs. Residential consumers are facing a choice between installing natural gas boilers (NGB), electric heat pumps (EHP), or connecting to a DE system (DES). These three scenarios have been compared in order to determine the most economically viable solution.

The City of Pittsburgh and DDEA used the City Council building in the comparison to determine the best option for efficient heating. This gives a realistic result as the building today is a customer on the PACT system (downtown Pittsburgh heating utility) and represents most of the system's customers. This analysis and conclusion can be applied to any building with a similar load of approximately 18,000 MMBtu/year.

DATA AND ASSUMPTIONS

When the comparison was made between the three choices, different assumptions were made, as shown below. A standard financing investment cost of a 5% interest rate paid over a ten-year period was applied.

RATE	UNIT	
DES		
Variable price	$/mmbtu	21.13
Fixed price		None
Natural gas, residential		
Variable price	$/mmbtu	15.41
Fixed price		None
Electricity, residential		
Variable price	$/kWh	0.14

PRICE ASSUMPTIONS	$
DES household unit	
Price	30,000
Efficiency	98%
Salary employees (#1)	50,000
O&M, household	1,000
Pipe infrastructure (paid by customer)	200,000
Natural gas boiler	
Price	400,000
Efficiency	86%
Salary employees (#3)	100,000
O&M, household	55,000
Pipe infrastructure (paid by customer)	20,000
Electricity heat pump	
Price	350,000
Efficiency	250%
Salary employees (#2)	100,000
O&M, household	55,000
Pipe infrastructure (paid by customer)	0

RESULTS

Calculating the heating cost yearly, the following result is presented.

YEARLY HEATING COST, TOTAL	$/YR.
District Heating	438,947
Natural gas, individual	471,213
Electric heating pump, individual	445,364

DIFFERENCE, ANNUAL $/YR.	DES	NGB	EHP
In total, annual heating costs and loan	468,733	525,605	490,691
Savings choosing District Heating		56,872	21,958

RETURN OF INVESTMENT COMPARE TO NGB	DES	EHP
Years	7.1	13.5

The comparison shows that the cheapest solution is to connect to the DE system to heat a large-scale building. When compared to the natural gas boiler, a saving of $56,000 can be made, and when compared to the electric heating pump, a saving of $21,000 can be made on a yearly basis. The return of investment is around 7 years based on these savings for connecting to the DE system and approximately 13.5 years for the electric heating pump. Additionally, the environmental benefits of a district heating system far outweigh the benefits of the other two options in Pittsburgh, where the electricity is produced based on coal, resulting in a host of pollutants and other negative environmental effects. District heating systems are far more resilient and dependable, give better indoor climate, and require less maintenance for the building owners.

PACT SYSTEM

INTRODUCTION

The City of Pittsburgh and the DDEA created this business case to advise PACT on how to best proceed with their energy investments. PACT is facing a decision on whether to completely reinvest in their current energy infrastructure, which needs major upgrades, or whether to convert the steam system into a DE system based on hot water. Current energy losses in the PACT steam system are estimated to be up to 15,000 MMBtu/hour, and system leak repairs cost approximately $40,000/year.

For customers to continue to use the system, PACT must keep energy rates anywhere from $17-$20/MMbtu to be compatible with other solutions like the natural gas boiler or the electric heat pump. In addition, the PACT system is losing its biggest customer, the County, which takes away 30 % of the total customer-based load.

DATA & ASSUMPTIONS	UNIT	
Efficiencies		
Steam production today	%	87
Steam production re-investment	%	90
Hot water production	%	98
RATE PRICES		
District Energy (Steam or hot water)	$/mmBtu	22.5
Water and sewage cost	$/mg	4.08
Electricity cost	$/kWh	0.065
O&M + ADMIN		
Steam production today	$/yr.	3,000,000
Steam production re-investment	$/yr.	2,700,000
Hot water production	$/yr.	1,500,000
Annual loan rate	%	3
Years of loan	Yr.	20

DATA AND ASSUMPTIONS

As with the residential, several assumptions have been made. However, PACT Operations Manager, Timothy O'Brien, has seen and verified the numbers. Data has also been collected from the PACT Masterplan by NRG, Burns McDonnell, and Ever-Green Energy, September 2016.

RESULTS

The first scenario of business as usual is set up without the consumer load of the County (30%). When investing in steam, the second scenario, the reduced heat loss during distribution in the pipes, further reduce the total heat load. The loss here is assumed to be 20% of the customer load. The third scenario includes converting the whole system to hot water, thus giving a reduced distribution loss of only 10 %. The numbers are shown without tax, and the investment is financed with a 3% interest rate paid over a twenty-year period. With the County leaving PACT, the business, as usual, will create a negative revenue of $220,000. The business-as-usual course of action is therefore not the future for the PACT system. However, the investment in the steam system gives a yearly revenue of a little less than $1 million. This yearly revenue can carry an investment of $14 million. Conversion to hot water leaves even more room for investment that could be as high as $36.5 million. The conversion also produces yearly savings in fuel due to less pipe loss and better production efficiency, and it reduces maintenance costs of operating and managing the new pipe system. Environmentally, this is also the best solution as the natural gas fuel is most efficiently utilized.

SCENARIO YEARLY, US$ EXCL. TAX	BUSINESS AS USUAL	INVESTMENT IN STEAM	CONVERSION TO HOT WATER
Heat load, without County incl. Loss, mmBtu	345,046	277,255	254,150
Income	5,198,524	5,198,524	5,198,524
Expenses	5,419,569	4,242,668	2,730,657
Revenue	-221,045	955,856	2,467,867
Investment		14,000,000	36,500,000
Annual loan payments (3%, 20 years)		941,020	2,453,373
RESULT OF YEAR	**-221,045**	**14,836**	**14,493**

CONCLUSION

As residents make the move to more sustainable and efficient energy solutions, so too must PACT. Through these business case scenarios, the DDEA and the City of Pittsburgh were able to lay out the different energy options for large consumers in the city. As shown in the results, the most profitable and reliable option long-term is to invest in DE based on hot water. Although the other options share some benefits, their environmental cost far outweighs these. The DE system is the future of thermal energy, and investing in this system will lead not only to monetary benefits but also environmental ones. To help the City of Pittsburgh reach its carbon and emissions goals and ensure a future that is energy efficient, the DE system should make a shift to not only hot water, but to renewable fuel sources. The benefit of warm water systems is that they can be combined with a long range of renewable solutions such as geothermal and solar heat, industrial waste heat and be more easily stored when having a surplus.

8. GLOSSARY

(CHP) COMBINED HEAT & POWER
CHP is an energy efficient technology that generates electricity and captures the heat that would otherwise be wasted to provide useful thermal energy—such as steam or hot water—that can be used for space heating, cooling, domestic hot water, and industrial processes.

(DE) DISTRICT ENERGY
DE is a centralized system for producing and distributing thermal energy in the form of hot water, steam, or chilled water to multiple buildings or facilities within a defined geographic area. It efficiently provides heating, cooling to reduce individual energy consumption and environmental impact.

(DH) DISTRICT HEATING
DH is a component of district energy systems where hot water or steam is centrally generated and distributed to residential, commercial, and industrial buildings for space heating and hot water needs. It enhances energy efficiency and lowers greenhouse gas emissions compared to individual heating systems.

(DC) DISTRICT COOLING
DC is an integral part of district energy systems that centralize the production and distribution of chilled water for air conditioning and cooling purposes in multiple buildings. It promotes energy efficiency and minimizes the environmental impact associated with individual cooling systems.

(RNG) RENEWABLE NATURAL GAS
RNG is a sustainable and environmentally friendly alternative to traditional natural gas, derived from organic materials such as agricultural waste, landfills, or wastewater treatment plants. RNG can be used for heating, electricity generation, and as a low-carbon fuel source, reducing greenhouse gas emissions.

(GHG) GREENHOUSE GAS
GHG refers to gases in the Earth's atmosphere, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), that trap heat and contribute to the greenhouse effect. Increased GHG concentrations in the atmosphere are a primary driver of global climate change and can lead to temperature rise and associated environmental impacts.

(O&M) OPERATION & MAINTENANCE
O&M encompass the activities and processes involved in the regular upkeep, monitoring, and management of various systems, equipment, or facilities to ensure their optimal functioning and longevity. O&M practices are critical for the efficiency and reliability of complex systems and infrastructure.

(PSI) POUNDS PER SQUARE INCH
PSI is a unit of pressure measurement. It quantifies the amount of force applied per square inch of surface area. PSI is commonly used to express pressure in various applications, such as in pneumatic systems and hydraulic systems.

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