European Commission

DISTRICT HEATING AND COOLING SOLUTION BOOKLET

Smart Cities Marketplace 2024

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ENERGY

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WHAT IS THE SMART CITIES MARKETPLACE?

The Smart Cities Marketplace is an initiative supported by the European Commission bringing together **cities, industry, SMEs, investors, banks, research and other climate-neutral and smart city actors**. The Smart Cities Marketplace Investor Network is a growing group of investors and financial service providers who are actively looking for climate-neutral and smart city projects.

WHAT ARE THE AIMS OF THE SMART CITIES MARKETPLACE?

The Smart Cities Marketplace has thousands of followers from all over Europe and beyond, many of which have signed up as a member. Their common aims are to **improve citizens' quality of life, increase the competitiveness of European cities and industry** as well as to **reach European energy and climate targets.**

WHAT CAN THE SMART CITIES MARKETPLACE DO FOR YOU?

Explore the possibilities, **shape** your project ideas, and close a **deal** for launching your smart city solution! If you want to get directly in touch with us please use info@smartcitiesmarketplace.eu

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WHAT AND WHY

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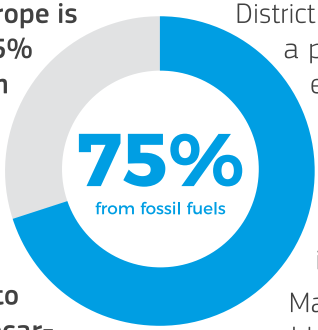
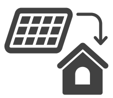
WHAT AND WHY

Half of the energy consumed in Europe is used for heating and cooling, and 75% of this energy is still coming from fossil fuels. Additionally, much of this energy is wasted due to inefficiencies in the heating and cooling systems. State-of-the-art, sustainable district heating and cooling systems offer a unique opportunity to make significant contributions to decarbonise EU cities through the efficient distribution of heat and cold from renewable energy sources.

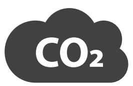


District heating networks (initially centralised heat production, delivered through distribution networks) have been present in cities for more than one hundred years, evolving from the early high-temperature heat distribution (steam) networks towards more efficient low-temperature schemes that reduce heat distribution losses and enable the use of renewable and waste energy sources, as well as the integration with the electricity grid. Also, current intelligent management systems allow for increased operational benefits and new paradigms such as decentralised networks.



Increased share of renewables

Air quality improvements



CO_2 emission reductions

District heating and cooling networks constitute a proven solution for large scale thermal energy distribution that has been deployed in a growing number of cities worldwide, using a diversity of technologies that can enable to develop synergies between the production and distribution of heat, cooling, domestic hot water and electricity.

Many district heating systems around the world require modernisation (i.e. retrofitting) to bring them to a reliable, state-of-the-art standard. Currently, district heating and cooling technologies enable the use of a variety of heat sources that would otherwise be often wasted, as well as of renewable heat. Nowadays, cities are looking at state-of-the-art district heating and cooling networks to achieve energy and climate related goals, including affordable energy provision; reduced reliance on energy imports and fossil fuels; local air quality improvements; CO_2 emission reductions; climate neutrality; reduced energy poverty; and an increased share of renewables in the energy mix.

Embracing sustainable district heating and cooling systems is not just a technological upgrade; it's a pivotal step toward a greener, more resilient future.

By harnessing renewable energy and optimizing efficiency, we can transform our cities into beacons of innovation and environmental stewardship.

Biomass district heating system in Vitoria-Gasteiz, Spain ©SmartEnCity

Sustainable, state-of-the-art district heating and cooling systems integrating renewable generation can present many **benefits for cities and society**, linked to both the local and global challenges urban environments are currently facing:

Efficiency benefits from centralised energy production (economy of scale)

Reduced greenhouse gas emissions from heating and cooling, minimizing CO_2 penalties and contributing to targets on emission reduction of the building stock

Good **synergy** potential with local renewable energy sources and waste heat/cold

Support of the other networks like the electricity network by using the **flexibility of the thermal network**

Reduced dependency on fossil fuels, reducing exposure to international energy trade

Stabilisation and reduction of heat costs

Supporting the **local economy** by keeping money in the region (strong mid-term effect allowing investments in further infrastructure and resilience)

Potential for **prosumers** in the network allowing to put excess building heating and cooling in the network

Local green jobs creation potential through increased focus on local energy sources

Potential **income sources** when combined with waste incineration or the use of other residual sources like landfill biogas and industrial or commercial waste heat

Better air quality, entailing reduced costs in the public health system.

CITY CONTEXT

CITY CONTEXT

"Today, around 75% of Europeans live in cities. Urban areas account for 60 to 80% of global energy consumption and around the same share of CO_2 emissions. Climate change has the potential to influence almost all components of the urban environment and raises new, complex challenges for quality of urban life, health and urban biodiversity. Climate change will affect many aspects of urban living from air quality to consumption patterns. The EU has put in place ambitious policies and initiatives to promoting solutions on the ground. These include initiatives to increase resilience and promote renewable energies and low-carbon technologies" [1]

This global urban concentration trend entails a **growing thermal energy demand in cities**, where domestic space heating or cooling and distribution of hot water are the main elements. Sustainable, state-of-the art district heating and cooling systems, together with sensible building retrofitting schemes, are one of the most promising technology combinations to address this urban challenge. The scale of district heating and cooling systems, in addition, can provide excellent opportunities to introduce smart features, such as thermal storage technologies and smart control, in a cost-effective way. However, district heating and cooling systems should be carefully designed considering the specific urban context they are to serve. Different aspects affecting energy demand, such as urban density, climate, building stock condition and local availability of excess heat sources or renewable energy sources will play a key role in selection and design of the most appropriate district heating and cooling system.

Specifically, in urban contexts, the existing building stock conditions as well as the potential trade-offs with building energy retrofitting policies and targets need to be carefully assessed[2]. Last-generation low temperature district heating and cooling systems might not be suitable for all urban and suburban scenarios, since they are best suited to low-demand, energy-efficient buildings. For this reason, careful attention must be paid to the context in order to design a district heating and cooling network and to select the technologies to be used. Heat zoning plans can be developed to assist in city-wide planning. They identify zones that can well be serviced by specific types of district heating and cooling networks, versus areas where 'stand-alone' solutions (for example, based on the use of individual heat pumps) will be more appropriate.

1 European Commission. EU Mission: Climate-Neutral and Smart Cities

2 H. Vandevyvere, G. Reynders, R. Baeten, I. De Jaeger, Y. Ma, 2019. The trade-off between urban building stock retrofit, local renewable energy production and the roll-out of 4G district heating networks

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What are cities able to achieve through district heating and cooling systems?

District heating and cooling systems deliver added value from many perspectives. Some real-world examples are listed below:

1. Through the **SINFONIA project**, Innsbruck's district heating network has been extended and optimised to increase its use of renewable energy sources by 95% and reduce the system use of fossil fuel by 22%.
2. Through the **Act!onHeat project**, several municipalities are being supported to accelerate their strategic heating and cooling planning, and develop district heating pre-feasibility studies.
3. **Islington Council's Bunhill Heat and Power Network** (BHPN) is the first scheme in the world to take waste heat from an underground train network and use it to provide lower cost, greener heat to local homes, schools and leisure centres.
4. In Mannheim, the local district heating operator MVV started the operation of a new large heat pump using water from the Rhine River, which will supply circa 3 500 households.
5. Started as part of the **Pitagoras Project**, 77 hectares of land have been secured in Graz for a solar thermal system with seasonal storage that will supply the city. The solar collectors will provide approximately 210 MW of peak power.
6. Danish cities have reduced their CO_2 emissions by 20% since 1990, reportedly due to district heating systems.
7. Paris has district heating systems at the core of its 75% CO_2 reduction strategy by 2050.
8. In Copenhagen, a waste-to-heat recycling process avoids 655 000 tons of CO_2 annually, displacing 1.4 million barrels of oil each year.
9. In Gothenburg, district heating production doubled between 1973 and 2010, while CO_2 emissions fell by half and the city's nitrogen oxide (NO_x) and sulphur dioxide (SO_2) emissions declined even more sharply, due to the reduction of fossil fuel use.

The CELSIUS initiative for Cities

Stemming from the successful, award-winning CELSIUS project, the CELSIUS initiative was a collaboration hub for efficient, integrated heating and cooling solutions supporting cities in their energy transition to carbon-neutral systems. CELSIUS gathered and shared technical, economic, social and policy expertise, allowing members to connect, exchange and foster innovation, leading to solutions that accelerate sustainable development in Europe and across the world. The **CELSIUS Tool-kit** aims to be a source of knowledge and inspiration for cities interested in developing district energy (district heating and cooling) solutions. It addresses cities which are just beginning to implement small-scale district heating and cooling networks as well as cities with large established systems endeavouring for even smarter and more efficient solutions.

> ***"The main challenge of these systems to become mainstream is their integration in existing environments. In new developments it is less challenging."***

Frank Soons, Sustainability and Innovation manager at Ennatuurlijk

Heat Zoning in your city

Municipalities can use heat zoning as a planning tool in their decision making towards design and deployment of district heating and cooling networks. Heat zoning plans are already compulsory in some EU countries and drive many cities in their strategies in transitioning towards clean energy.

By mapping and quantifying locally available renewable energy and waste heat sources, as well as heat demand in urban and suburban environments, an initial assessment on whether district heating or cooling networks are desirable or not can be made, including initial considerations on the type of technologies to be used.

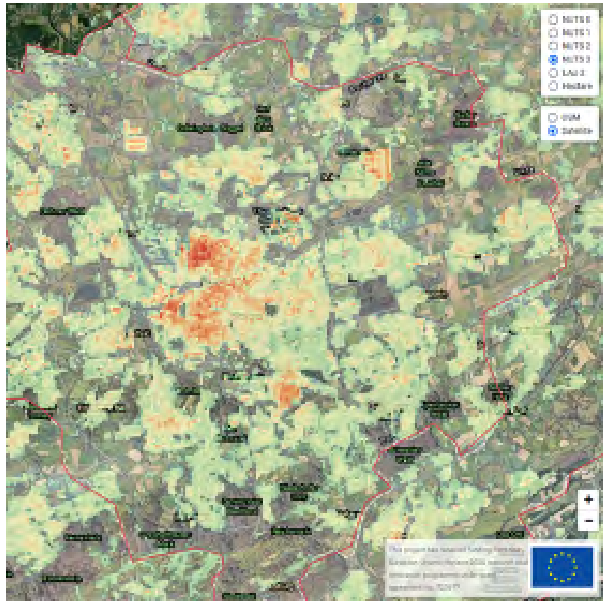
Although the preparation of proper heat zoning plans entails much locally sourced, detailed information, a good starting point can be the **Pan-European Thermal Atlas** (PETA), produced by the Heat Roadmap Europe project, which maps diverse parameters related to thermal energy in EU cities: heat and cold demand, district heating distribution costs, geothermal heat potential, biomass resources, excess heat resources, district heating recommendation levels, etc. The Heat Roadmap Europe project created scientific evidence to support the decarbonisation of the heating and cooling sector in Europe, concluding that CO_2 emissions can be reduced by 4 340 M ton or 86% compared to 1990 using only known technology in the sector.

Another useful tool for heat zoning is the **Hotmaps tool**, produced by the same named project. This tool allows public authorities to identify, analyse, model and map resources and solutions to supply energy needs within their territory of responsibility in a resource and cost efficient way.

Heat zoning empowers cities to strategically harness local renewable resources and waste heat, paving the way for a sustainable energy future. By leveraging tools like the Pan-European Thermal Atlas and Hotmaps, municipalities can make informed decisions that drive the transition to clean, efficient district heating and cooling networks.

Heat demand in Oresund area; Copenhagen, Malmö and Lund ©PETA

Heat density in Dortmund ©Hotmaps



SOCIETAL AND USER ASPECTS

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SOCIETAL AND USER ASPECTS

Stakeholder support and citizen engagement

Developing district heating and cooling systems can be a challenging action, mainly in areas where energy supply is based on individual production systems.

This change involves actions in both the domestic and community spaces, as well as implies a shift of paradigm for people, who are used to behaving in a particular way during their daily life. Structural changes to these routines can generate social resistance. Therefore, it is important to **carefully inform and involve key local stakeholders and citizens** in these shifting processes, explaining very well the procedures and benefits entailed to the new approach.

For effective community engagement, the city may well set up a collaborative reflection process regarding the integration of district energy systems. When this process is well developed and designed with a relevant target in mind (e.g. city carbon neutrality), **future plans, strategies, commitments and projects** will be shared by the community, enforcing the feeling of belonging and contribution to a shared meaningful goal by everyone.

There are two main stages when this engagement can be fostered:

1. The **city energy visioning**, where the municipality can co-formulate key goals, strategies and projects with key local stakeholders and citizens.
   - For an engaging city energy visioning process, check [Sonderborg Roadmap2025.][3]
2. The **master plan design**, where the municipality, key stakeholders and future customers can exchange views about the system and its features/conditions with the promoters. This is key as long-term commitments are necessary to confirm the viability of operations. At this stage, it is crucial to involve the main groups of the area addressed by the master plan in order to inform them and avoid foreseen barriers.
   - For an engaging master plan, check the stakeholder involvement in Lolland municipality.[4]

For such large-scale actions, a **city partnership** joining the municipality, all district energy utilities, citizens' and business associations, and large heat/cold consumers is highly recommended.


City energy vision


Master plan design


City partnership

3 Sonderborg Roadmap2025. 50 steps towards a carbon neutral Sonderborg
4 Broad stakeholder involvement in district heating masterplan for Lolland municipality

Main benefits for stakeholders

Broad **societal benefits become tangible for stakeholders involved** in district heating and cooling operations; particularly, end users can feel significant differences when this system is compared to the traditional individual production systems:

- **More reliable energy source**, even working at extreme weather events.
- More **predictable energy costs** due to fuel source flexibility. The **exposure** to fluctuating gas and electricity prices is **reduced**.
- Ability to pursue better **long-term energy contracts**.
- **Increase of indoor space and safety and reduced indoor noise and pollution** by externalising thermal energy production, fuels and storage from the building.
- **Lower overall operation, maintenance** and insurance costs.
- **Easier upgrade/replacement of equipment (centralised)** to more efficient and cleaner technologies.
- Usage of flex in the network to better **balance heat demand with RES and waste heat and cold** (e.g. building mass, decentralised and centralised storage, storage in the network piping.
- Potential for including **long term seasonal storage** like ATES, BTES, CTES and pit storage.

For further reference, please visit this report from the **CELSIUS Toolkit** on Stakeholder engagement in heat networks.

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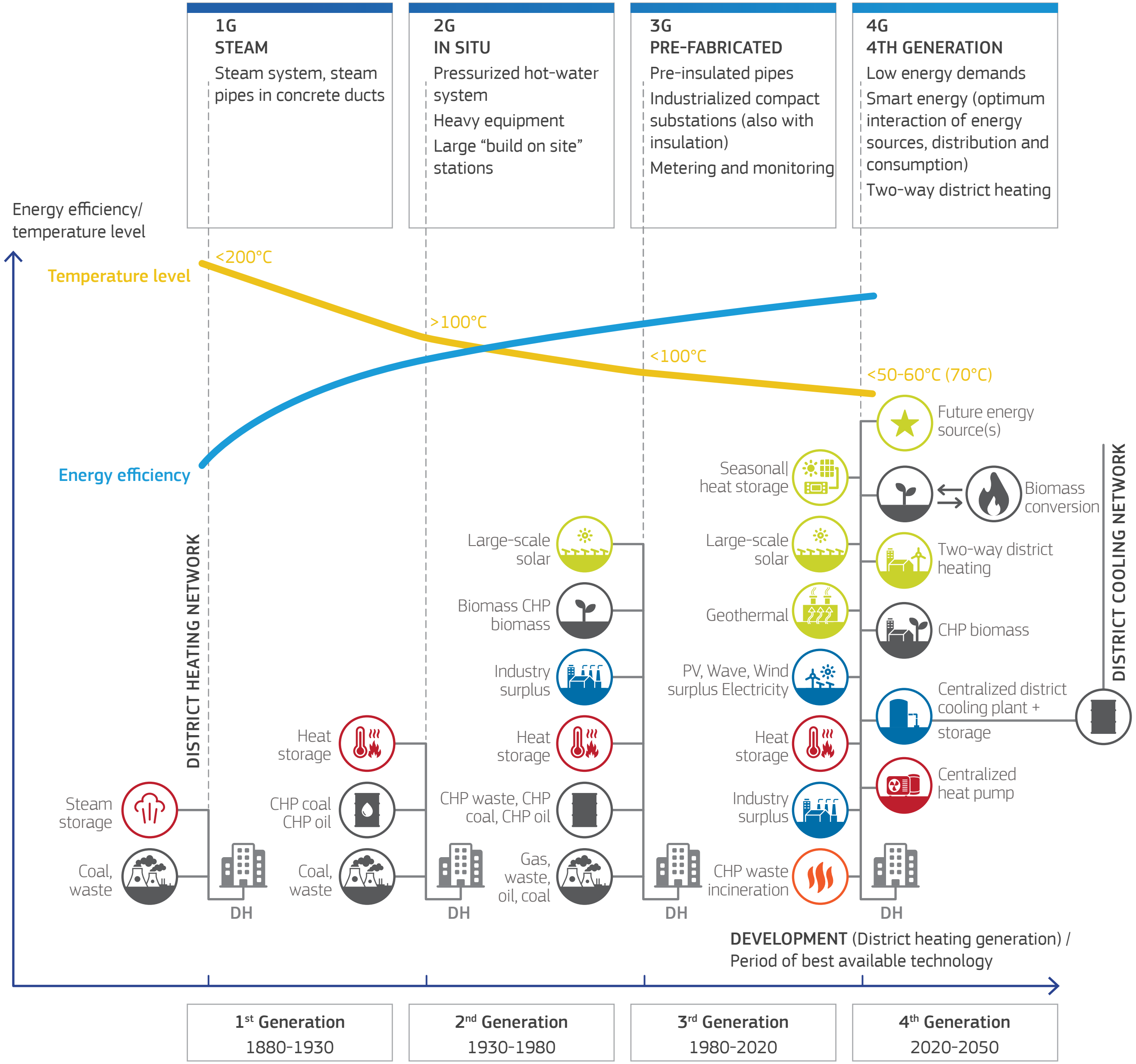
TECHNICAL SPECIFICATIONS

TECHNICAL SPECIFICATIONS

Technology evolution

Since the initial district heating system deployments over a hundred years ago, development of district heating systems has gradually achieved higher levels of efficiency, a more widespread diversification of heat and cold sources, and increased potential of integration with the electricity grid. This is a direct consequence of technologies and processes that gradually enabled the use of lower operating temperatures.

Through the conversion systems (e.g. electricity into heat, combined heat and power) with subsequent heat storage, smart system management and flexible demand, these systems present moreover an inexpensive solution for creating the flexibility required to integrate high levels of variable renewable energy into the electricity grid. Such smart exchange between electricity networks and thermal networks is better known as sector coupling.



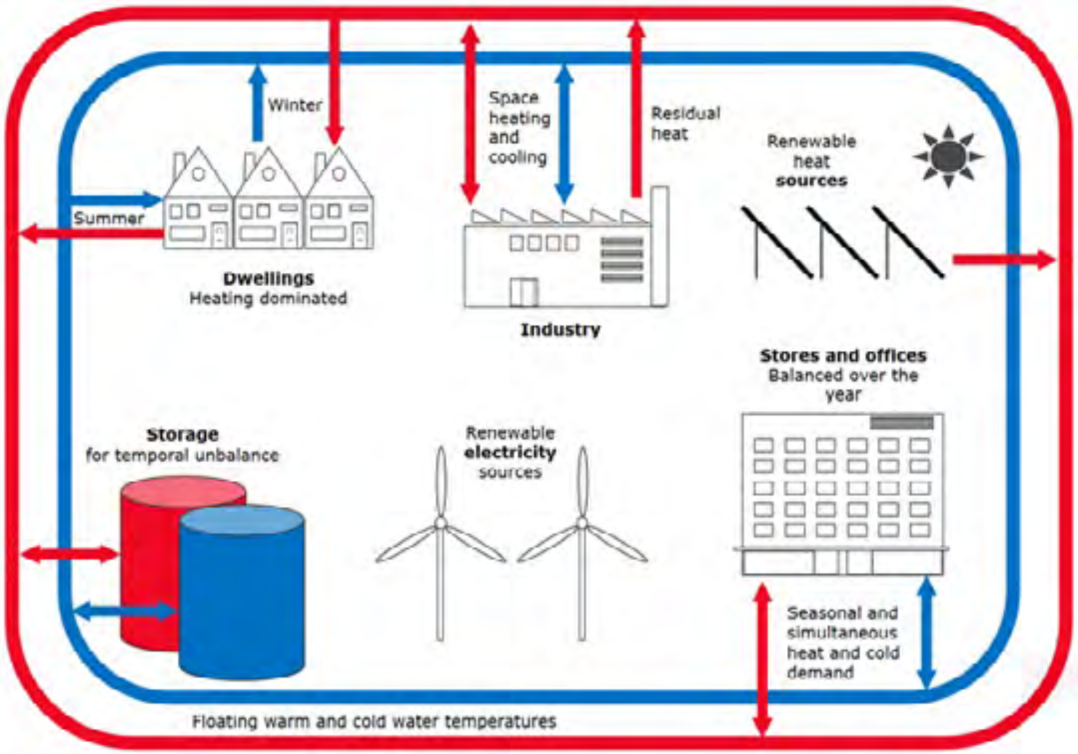
Historical development of district energy networks. Adapted from ©Aalborg University and Danfoss District Energy, 2014

So-called fourth-generation systems are located closer to load centres and generators than traditional central-station generating plants, and the distributive nature and scale of these systems allow for a more nodal and web-like framework, enhancing accessibility to the grid through multiple points.

The fifth-generation district heating and cooling systems (5GDHC) are those that using local renewable energy systems allow to recover heat generated from cooling and cold generated from heating. As the system is non-linear, bidirectional, and decentralised, it allows consumers to be producers. When the heat and cold demands are similar in size, it can create an almost circular system. (Source: ADGEO)

However, 5GDHC are often considered a subclass of 4th generation systems, as they can be in many ways less beneficial than the 4th generation systems if only heating is considered. (Source: IEA DHC)

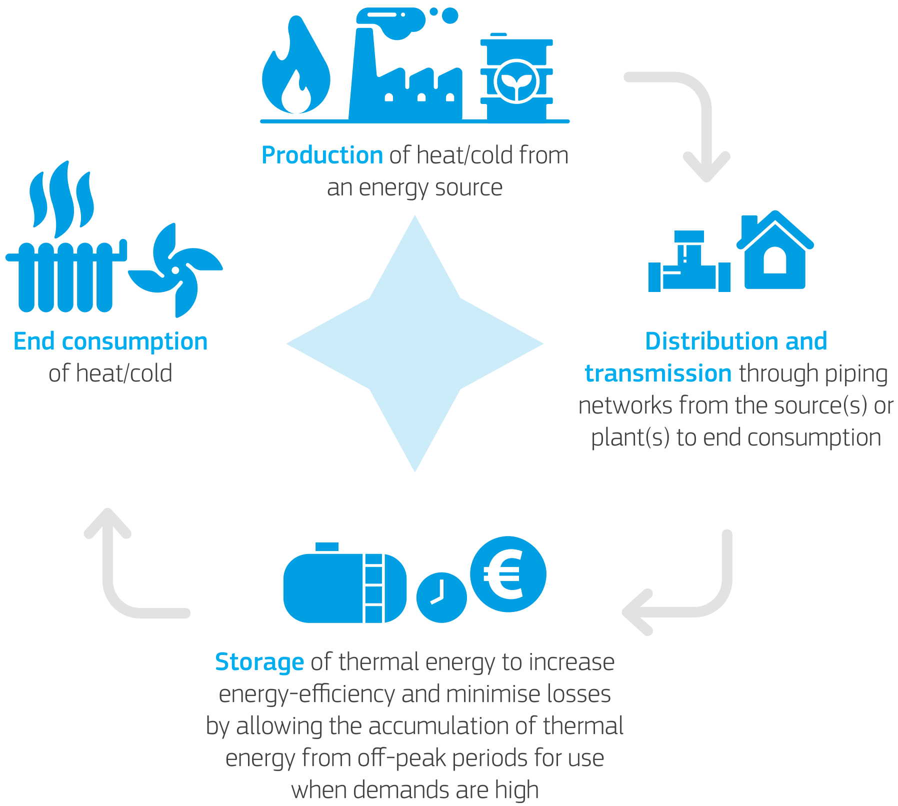
The **D2GRIDS project** aims to develop 5th generation urban heating and cooling networks (5G DHC) in Europe. The objective is to maximize the share of renewable energies in these local energy loops, through an industrialization of the approach, a standardized technological model, and a clarification of the business model to strengthen the interest of these projects for third party investors.



A circular representation of a 5GDHC system. ©"**5th generation district heating and cooling systems as a solution for renewable urban thermal energy supply**", 2019

Components and technologies

According to their main functions, district heating and cooling systems can be broken down into **four different parts:**



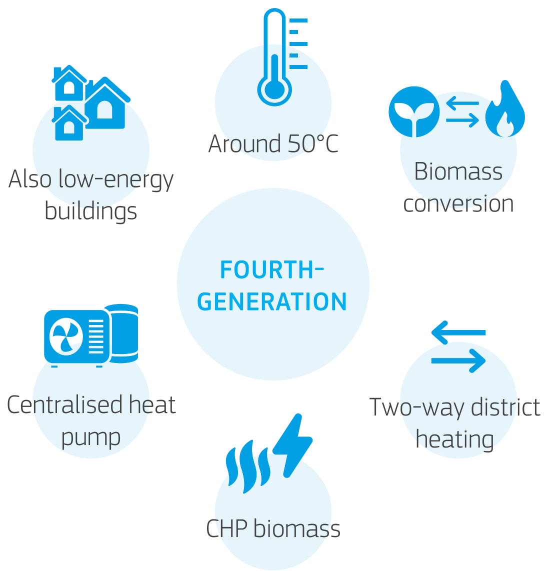
Through the European **City-ZEN project**, the city of Grenoble implemented different storage solutions such as seasonal storage with dry geothermal boreholes, centralised phase change materials storage to help meet peak demand for heating and solar thermal generation coupled with phase change material (PCM) storage solutions.

Achieving sustainable modern district heating and cooling begins with the energy source. New-generation district heating and cooling systems lean towards decentralised generation of heat and cold, taking advantage of all available local energy sources – many of which are renewable or residual heating and cooling and produce minimal greenhouse gas emissions.

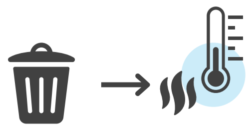
Technologies for District Heating

Current district heating enables the use of a variety of heat sources that are otherwise often wasted, as well as of renewable heat.

Modern (fourth-generation) systems operate at lower temperatures (typically around 50 - 60°C), resulting in reduced heat loss compared to previous generations, and making it feasible to connect to areas with low energy demand buildings. Fourth and fifth generation systems can use diverse sources of heat, including low-grade waste heat, and can allow consumers to supply heat as well.



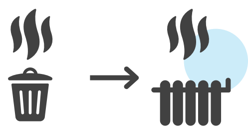
The main heat generation technologies currently in use are the following:



Waste to energy:

Energy content of municipal solid waste (MSW) and other combustible wastes is reused through incineration in a plant for heat production.

This technology produces low-cost heat and can be paired with electricity production as well; it has been often used in the initial development of a city's district heating network. Potential air pollution can be a problem addressed in modern incinerators, that require lesser distances to the city.



Waste heat recovery:

Waste heat from nearby industrial processes, as well as low-grade heat from sewage can be reused in a district heating network.

This increases energy efficiency of the overall system, as part of a circular economy. Typically, these waste heat sources will not guarantee supply, and may require some degree of redundancy in the system.

The **THUNDER project** aims to overcome existing barriers hampering a wide adoption of data centres waste heat recovery strategies, providing an innovative, efficient and cost attractive Seasonal Thermal storage based on Thermochemical Materials.

Through the **Pitagoras Project**, a pilot plant in Brescia that uses high temperature waste heat recovery (≈600ºC) from a steel foundry and Organic Rankine Cycle (ORC) unit (2.1 MWe) for heat and power generation, is connected to the existing city district heating network.

Through the **Growsmarter project**, the city of Stockholm is utilising waste heat from the sewage system, from data centres and from fridges and freezers in supermarkets to feed it into the city district heating network.

Islington Council's Bunhill Heat and Power Network (BHPN) is the first scheme in the world to take waste heat from an underground train network and use it to provide lower cost, greener heat to local homes, schools and leisure centres.

Biomass/Biogas:

Biomass and biogas systems create energy from renewable organic matter. In order to be sustainable, the used biomass will preferably come from waste streams or be locally sourced from sustainable production.

Non-waste resources may be used if an environmental impact assessment proves their sustainability. Materials once considered waste, such as clean wood construction waste and other wood residue sources (slash piles, hog fuel, etc.), can be put to good use. Methane gas produced in decomposition of garbage and manure can be collected and used in a power plant to generate electricity and heat, or sold as a renewable natural gas source. Combustion eventually combined with prior gasification of residual wood biomass or wet biomass waste streams delivers thermal energy in the form of steam or hot water. As the produced heat has a high temperature, it can be used both for heating and for electricity production (using a CHP plant).

Through the **SmartEnCity project**, Vitoria-Gasteiz is deploying a new biomass (wood chip) district heating network with advanced management and control capabilities integrating demand and supply.

Geothermal

Geothermal installations use the thermal energy beneath the earth surface. They can be categorized based on their depth as shallow, medium or deep geothermal systems.

These installations harness heat from the surrounding ground or an aquifer, with temperatures ranging from low single-decade temperature to over 200 °C for heat purposes. The geothermal source can be directly used for the network or, in case the temperature is too low, used together with a large heat pump. It is a renewable, present anywhere and environmentally friendly technology with high operational stability and lifetime, best oriented to producing base-load heat. Medium and high temperature resources are available in certain areas only and present high upfront investment costs and relative uncertainty in resource availability. Financial models and de-risking instruments are required to overcome these barriers and allow project development and a lifetime operation of more than 30 years with low O&M costs.

Solar thermal

Energy from the sun can be harvested with thermal solar collectors and used to feed a district heating system.

Different solar collector technologies (flat plate, vacuum tube, double covered flat plate, vacuum flat plate solar collector) can be used depending on the district heating temperature. Since solar energy is intermittent and seasonally variable, district heating networks with solar thermal energy are usually combined with other fuels or seasonal storage systems, which allow shifting the delivery of solar heat from periods of higher production and lower demand (summer) to the heating season. Flexible configuration of solar collectors (e.g., solar field vs. distribution over different buildings in an urban area) can also facilitate the decentralisation of systems. Solar Thermal heat is already used in more than 270 European cities to support heat generation 100% emission free.

Solar energy collected from PV panels producing electricity can also be used in district heating and cooling schemes, in combination with electric boilers or heat pumps, and heat storage solutions, particularly in new networks. This way of coupling the electricity and heating systems can help to efficiently manage intermittency from solar PV (and other renewable electricity sources like wind) at an affordable cost. Dependency from the sun or wind means that a backup/peak load source is required.

District heating boilers

Boilers burn fossil fuels (natural gas, oil products, coal) or renewable fuels (biomass, biogas) to produce heat. This is a highly flexible heat production technology, used to cover base loads with minimum CO_2 emissions (through renewable fuels sustainably and locally sourced) and to provide peak load supply (gas, oil, coal).

Combined heat and power (CHP)

This technology simultaneously produces electricity and heat. The electricity generation turbines can be fed by fossil or renewable fuels in mid-sized to large, centralized plants, and the surplus heat can be used in a surrounding district heating network. It can operate to follow both heat demand or electricity prices and is best used in combination with heat storage technologies.

> ***"A combination between wind power or PV, air-to-water heat pumps, and storage of cold and heat seems the way to go in district energy systems, with currently similar prices to a biomass-based boilers supply."***

Per Alex Sørensen, DHC consultant at PlanEnergi

Kortrijk Weide, a DHC project in Belgium ©Agata Smok

©Agata Smok

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Heat pumps

Heat pumps use electricity to extract heat from free, renewable low temperature sources (ambient air, water, ground, waste heat…). They need a small amount of energy to turn the free thermal energy into energy at useful temperature levels.

There are many different types of heat pumps that could be used, but they all have in common that they need a low temperature heat source and energy. Although high temperature heat could be supplied by specific heat pumps, the efficiency is better with low temperature lift. The heat pump works on four main principles: liquid or gaseous state, temperature, pressure and volume.

Refrigerators are a common example of this technology: the small heat pump that is installed in fridges extracts heat from the air on low temperature inside the fridge and releases the heat through the heat exchanger on the backside of a fridge to the air in the kitchen.

There are different types of heat pumps depending on the energy source that is used:

- **Air source heat pumps use outside or ventilation air for heating, cooling, and hot sanitary water.** They can be installed indoors, outdoors, or with units both inside and outside.
- Water source heat pumps extract energy from groundwater, surface, or sea/sewage water efficiently.
- **Geothermal heat pumps extract heat from the ground or groundwater through a borehole heat exchanger.** During the process, the heat is transferred to a refrigerant in a heat pump unit, further elevating the temperature for distribution in the district heating network.
- **Electrically driven heat pumps are common, powered by electricity for compression cycles, which can be connected to renewable sources for sustainability.** Combined with large thermal storage, electric boilers, and CHP, heat pumps help reduce the overall electricity demand for heating and cooling by integrating non-electric heat sources.

As temperature of district heating networks as well as temperature demand of buildings vary, different layouts of heat pump driven heating networks have been developed. Different potential configurations are:

- **District heat pump:** a central heat pump, a district heating network and heat exchangers in the different buildings.
- **Building heat pumps:** having the low temperature being distributed in a network, combining that with a heat pump at building level for multiple users in the building.
- **Individual heat pumps:** the district heating network distributes the low temperature heat and the individual users each have their own heat pump.
- **Combination:** a combination of previous systems allows an even wider flexibility in fulfilling the heating demands of various end-consumers and optimising the operation and efficiency of the network.

Heat pumps have a high efficiency rate (which depends on the difference between the used source temperature and the desired temperature). Some models are reversible, capable of producing both heating and cooling. Additionally, use of heat pumps promotes synergies with the electricity grid. In combination with city-scale thermal storage, large heat pumps can absorb excess renewable electricity (for direct or postponed use) and modulate production to ensure grid balancing and provide weekly or even seasonal flexibility.

Some of the benefits of Heat pump driven district heating systems include: the decrease in thermal losses; enabling end-consumers to take a more active role in the energy system; alternative pricing models with a lower dependence on electricity prices; include waste heat; use all kind of thermal flexibility in the thermal network, create local jobs; contribute to improved air quality by avoiding the use of fossil fuels; increased share of renewables.

Heat pumps offer a powerful, efficient solution for tapping into renewable thermal energy sources, driving the transition to sustainable heating and cooling systems. By integrating with district heating networks, they reduce reliance on fossil fuels, improve air quality, and create new opportunities for energy flexibility and local job creation.

Within the **REWARDwHeat** project, the Helsingborg demo site comprises a newly constructed low-temperature sub-network that uses a borehole seasonal thermal energy storage system with a centralised heat pump. During the summer, industrial surplus heat will be used to charge the borehole store. The network will provide domestic hot water and space heating to four residential buildings (110 units) and one office building. The office building will also have district cooling. The network is made up of a 4-pipe distribution system that runs at 40°C to provide space heating and at 60°C to provide residential hot water.

Helsingborg, Sweden by night ©Hanseric Orre, Unsplash

Technologies for District Cooling

District cooling can be more than twice as efficient as traditional decentralised chillers such as air-conditioning units. It can reduce electricity consumption significantly during peak demand periods through reduced power consumption and the use of thermal storage. Use of free-cooling technologies can further improve these benefits.

The integration of mixed heating/cooling networks is made possible by current technologies; this facilitates the increasing relevance of district cooling as cooling demand surges worldwide, spending on energy services increases, climate change effects become noticeable (heat waves, but also average temperature rising) and the population in cities increases.

Adoption of district cooling schemes in urban settings can also help to reduce the use of environmentally damaging refrigerants such as hydro-chlorofluorocarbons (HCFCs) and hydro-fluorocarbons (HFCs). Both refrigerants are one of the main causes of ozone layer depletion and present strong global warming potentials (GWPs) at the same time

The main technologies currently in use for district cooling are the following:

Electric chillers

Electric chillers use electricity to power a vapour compression refrigeration cycle. In comparison with decentralized air conditioning, they average better efficiency, and use refrigerants with less global warming potential (GWP).

Absorption chillers

This kind of chillers use surplus heat from different processes (industrial heat, waste incineration, commercial uses, solar heat...), achieving high energy efficiency and using environmentally-friendly refrigerants. It is frequently combined with CHP to seasonally adjust its operation. This technology can be combined with district heating networks, as heat from the network is used for the absorption system in the building to deliver cooling.

In the **AZ St.-Jan Hospital** at Bruges, Ingenium developed a refrigeration system with an output capacity of 4.8 MW, by transforming the residual heat of the incinerators of the local waste processing plant IVBO into ice water at a 6/12°C regime by means of absorption coolers.

Free cooling

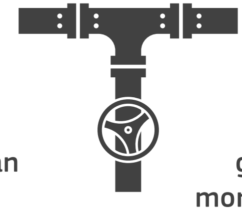
This technology uses natural (water bodies mainly) or waste cool sources. Seasonal availability of the resource, and the need for environmental permits and associated costs need to be factored in.

Through the **READY project** , the city of Växjö (Sweden) has connected two district cooling networks as to increase the renewable energy sources input and increase the amount of waste heat used in the system. The integration of the city district heating network and the district cooling network is performed with absorption cooling machines, making it possible to produce cooling with heat when the electricity price is high and to produce cooling with electricity when the price is low.

Växjö, Sweden ©Nazrin Babashova, Unsplash

Distribution

Distribution networks manage the delivery of heat to the end users and the return of lower temperature fluid to the heat production facility. Several configurations can be used based on specific needs (scale, temperature, operating pressure, building connections…). District heating and cooling networks differ in size, layout and conditions in cities and urban areas around the world. .



The piping is often the most expensive portion of district networks and usually consists of a combination of pre-insulated and field-insulated pipes (the larger pipes are mainly field-insulated, and the local ones are mainly pre-insulated) in both concrete tunnel and direct burial applications. The upfront investment for the transmission and distribution system, which usually constitutes most of the capital cost for the overall system, often ranges from 50% to 75% of the total cost for district heating or cooling systems. Because the initial cost is high in distribution systems, it is important to optimize its layout and use. The progressive adoption of low temperature and pressure networks, together with the more widespread use of insulated pipes and leak detection technologies have allowed for reduced heat losses and the corresponding substantial increase of efficiency in heat distribution.

Storage

Heat storage technologies are key for current district heating and cooling systems. They contribute to reducing the gaps between heat demand and generation caused by both time difference due to intermittence of heat generation sources (e.g. solar), or cost fluctuations of the thermal energy throughout the day. In general, heat storage can also allow for more stable and efficient heat production operation, and for the enhanced integration of variable renewable energy sources into the power system through sector coupling.

Heat storage technologies offer many options, which need to be carefully assessed according to the design specifics and operational demands of every case: thermal energy can be stored daily or even seasonally, allowing the decoupling of heat demand and production and enabling heat to be supplied in the most cost-effective way. There are several available technologies for this, which can be classified according to the physical phenomenon used for heat storage (sensible, latent or chemical heat storage), to the location within the network (centralized or distributed), or to the time span of the storage (daily or seasonal storage).

While latent and **chemical heat storage technologies** are currently less developed, **sensible heat storage** (where advantage is taken from temperature changes in the storage material) is the most mature and widely used for both short-term (daily, e.g. water tanks) or **seasonal (e.g. boreholes, tanks/pits, aquifer…) storage**.

Also the building mass of the buildings can be actively used to store heating for a shorter period. The water and the piping of the thermal network can also be used for short term storage. Smart control of the storage options is important in that case[5].

RE/SOURCED project at Transfo in Zwevegem, Belgium is a former electricity power plant which has stopped its production in 2001. The Municipality of Zwevegem became owner of the site and since then, three partners (the municipality of Zwevegem, intercommunal organization Leiedal and the Province of West-Flanders) combined forces to reform the entire site: buildings were restored, and new partners were recruited to give the site a new meaningful function.
©leiedal.be

5 Further reading: STORM District Energy Controller

End Consumption

In addition to heat generation, distribution and storage, the in-building equipment (or customer installation) necessary for end user consumption needs to be considered as well.

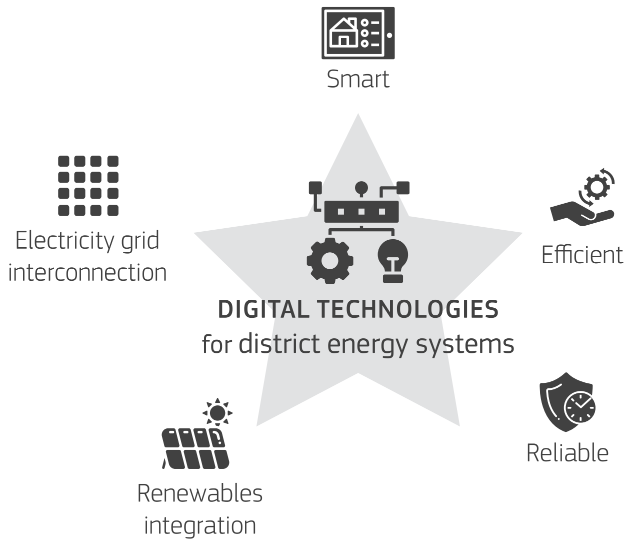
There are two main components for the customer installation:

- The in-building heat distribution system (radiators, pipes, HWD system), which may vary.
- The substation connecting the general distribution network with the in-building heat distribution system. A heat exchanger transfers heat from the distribution network to the building system and can be coupled with additional equipment such as individual heat storage or accumulation tanks, or a heat pump for temperature boosting in case of low temperature networks. Control and billing systems are often installed with the substation. In the houses individual heating interface units are used to deliver control the heat delivery to the individual heating system (e.g. radiators, floor heating) and the sanitary hot water.

Architectural integration of a district heating water storage tank in Hildesheim. Lighting colour fades from red to blue according to the amount of energy stored in the tank. ©Lighting design

Digitalisation in district energy systems

Digital technologies are being integrated into district energy systems in order to make them smarter, more efficient, and reliable. They also help to boost the integration of renewable sources into the system, as well as the interconnection with the electricity grid. In the future, smart management systems will enable district heating and cooling networks to fully optimise their plant and network operation while empowering the end consumer. These connected infrastructures will be used as efficiently as possible, time their production according to forecasted demand and maximise the use of renewable and waste heat energy sources and the usage of thermal flexibility.



Digitalisation will enable....

At Production Level:

- The simultaneous integration between production and consumption control systems.
- The consumers to adopt an active role in selecting tariffs and to contribute to demand side management.
- The network operators to have the “power to operate” substations themselves, so that they can control the demand side with an extra degree of freedom to optimise the efficiency at system level.
- Increased flexibility and the development of effective forecast models of the network through machine learning approaches and data-driven, real-time models.

At Distribution Level:

- Automated fault detection supervision to recognize anomalies in the networks and the buildings’ substations.
- The development of advanced self-learning digital twins, based on artificial neural networks, of the thermo-hydraulic networks with which one can:
  - Monitor and remotely operate the network
  - Simulate and evaluate operation and renovation scenarios
  - Test new operation algorithms and assess their performance before physical implementation.

At Building Level:

- The development of the connection between operational grid optimisation and efficient heating controllers (implying demand side management, for example through heat buffering in the building’s structure and decentralised (water) storages).
- The cost-effective communication and data management hardware/software of substations.
- The development of integrated control solutions allowing for the efficient operation of hybrid solutions combining DHC and individual heat pumps.

The **STORM project** is developing an innovative district heating & cooling (DHC) network controller, based on self-learning algorithms, in order to maximise the use of waste heat and renewable energy sources in DHC networks. This controller is tested and assessed in two demonstration sites, Mijnwater BV in Heerlen (the Netherlands) and Växjö Energi in Rottne (Sweden).

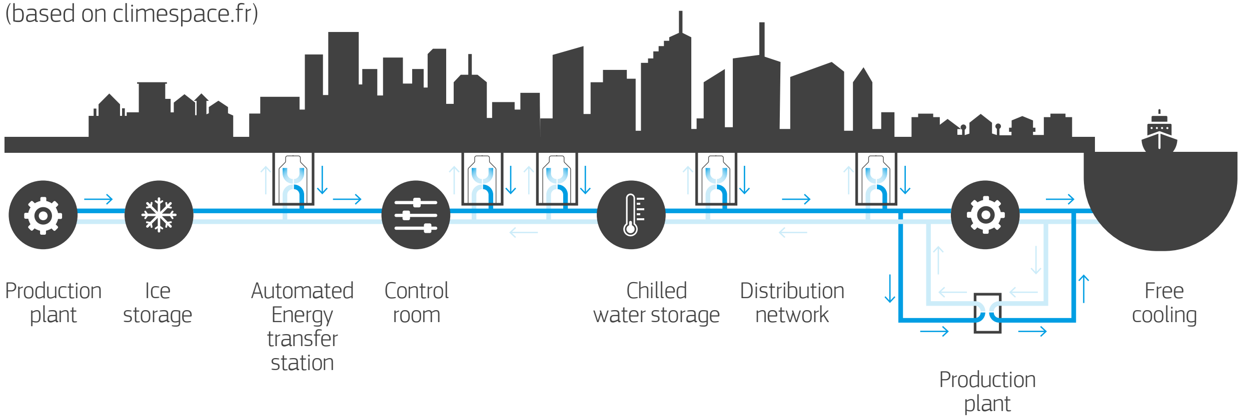
THERMOS is a free, web-based energy planning software that provides accurate heat and cold network options analysis instantly within one web-based, user-friendly tool. Developed by the THERMOS EU-funded project, the software is designed to optimise local district energy network planning processes to facilitate the deployment of new low-carbon heating and cooling systems and a fast upgrade, refurbishment, and expansion of existing systems.

PATHOPT is an optimisation toolbox for thermal networks that can automatically determine the optimal network layout based on specific geographical information.

> ***“Digitalisation is key in the evolution of these systems; we can improve 10 to 20% their efficiency by monitoring leakages, heat losses, better insulation configurations. The next step is to use digitalisation to influence the demand side (alarms, incentives, etc.) to reduce peak loads.”***

Frank Soons, Sustainability and Innovation manager at Ennatuurlijk

District cooling principle
(based on climespace.fr)



BUSINESS MODELS AND FINANCE

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BUSINESS MODELS AND FINANCE

Description – possible business models

The business model for a district energy system is very project specific. It needs to ensure that all the players involved – including investors, owners, operators, utilities/suppliers, end consumers and municipalities – can achieve financial returns, in addition to other benefits that they might seek like low energy costs.

Showcasing innovative approaches from cities around the world can help planners make better-informed decisions on how to develop and financially structure a district energy system. Categorisation of such approaches can help planners identify similarities that may apply to their own cities and distinguish specific circumstances.

When designing a business model for a new district energy system, it is important to consider site-specific circumstances, including the type of project finance that is available. Most business models for district heating and cooling networks involve the public sector to some degree, whether as a local policymaker, planner, regulator or consumer, or more directly through partial or full ownership of projects.

Public sector involvement can be critical in coordinating diverse projects around a broader city-wide vision. Even projects with a high degree of private sector control are often still facilitated or supported by the public sector. Although the business models and ownership structures described here vary significantly, they can be grouped along a continuum from public to private.

The involvement of the public or private sector depends broadly on three factors:

1. The return of investment for project investors,
2. The degree of control and risk tolerance taken up by the public sector,
3. Regulatory framework.

©Gary Stearman, Unsplash

Return on Investment (ROI)

The ROI is a financial metric that is dependent on both a project's Internal Rate of Return (IRR) and its Weighted Average Cost of Capital (WACC). The IRR is extremely site-specific and is developed initially by the project sponsor, which could be a private district energy company or private utility, or a public body such as a local authority or public utility.

The IRR will depend on the costs and incomes of the project. The WACC depends on the project's risk profile and its current and future sponsors, as well as on the debt-to-equity ratio of its financial structuring. Typically, while private sector investors will focus primarily on the financial IRR of a given project, the public sector, either as a local authority or a public utility, will also account for additional socio-economic costs and benefits that are external to standard project finance.

> *"Initial investment costs are high and constitute a big potential barrier. If there is a private business case, everything is easier (...) It's important to keep in mind that Distribution Systems (pipes) are the most expensive component. The first economic estimation must consider a pre-calculation according to the piping system; otherwise it will entail too much uncertainty"*
>
> Per Alex Sørensen, DHC consultant at PlanEnergi

What is the Internal Rate of Return (IRR)?

The IRR is the interest rate at which the net present value of all the cash flows (both positive and negative) from a project or investment equal zero. The IRR is used to evaluate the attractiveness of a project or investment. If the IRR of a new project exceeds a company's required rate of return, that project is desirable. If the IRR falls below the required rate of return, the project will be rejected.

What is the Weighted Average Cost of Capital (WACC)?

The WACC is the average rate of return a company expects to compensate all its different investors. The weights are the fractions of each financing source in the company's target capital structure.

Degree of control and risk tolerance by the public sector

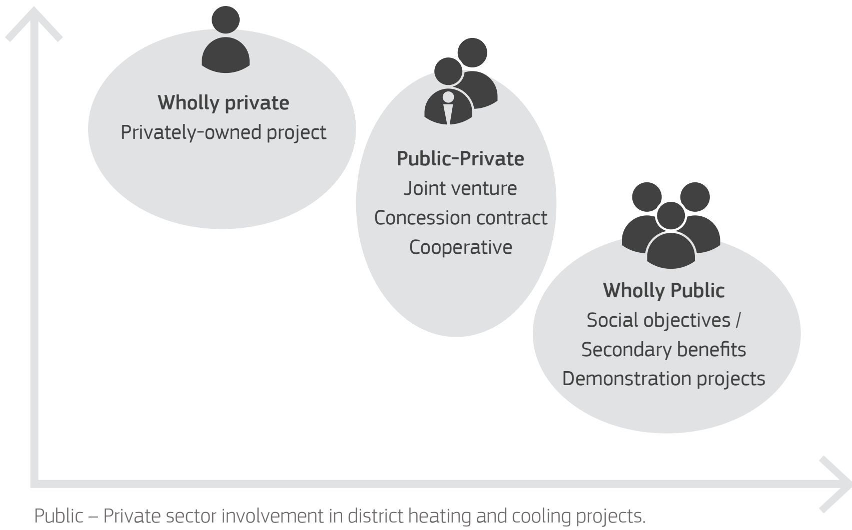
The public sector may wish to steer a district heating or cooling project towards a variety of local objectives, including cheaper local energy for public, private and/or residential customers; local job creation; local wealth retention; low-carbon power generation and renewable energy input; and/or local air pollution reduction.

By quantifying these objectives through economic modelling, it is possible to realise additional ROI outside of the standard financial modelling. Such advantages are also called secondary benefits and they provide a strong incentive for public authorities to invest in societal value beyond a mere financial business case, effectively increasing the financial risk a local authority could be willing to admit (risk tolerance), when compared to a primarily private driven investment. Local authorities may have a specific interest in controlling the roll-out of district heating and cooling infrastructure with a view on realising this surplus societal value. The degree of public sector control over a project can vary widely, ranging from full development, ownership and operation to a role focused mainly on project coordination, local planning and policy (see also the Governance section). The public sector also may wish to showcase the business case for district energy projects in the city by developing demonstration projects. Some cities and countries are more inclined to have energy services provided by public utilities, while others are more open to private sector participation.

The degree to which private sector involvement in the district energy provision is the norm will influence the business model.

The involvement of the public sector is however important in project development because of its:

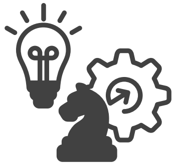
- Regulatory role,
- Ability to leverage finance for projects, such as through access to senior levels of grant funding and better access to capital,
- Ability to be a large, stable consumer and to provide off-take agreements, and
- Longer-term planning focus, greater interest in meeting social and environmental objectives and ability to coordinate the multiple stakeholders involved in district energy.



Public – Private sector involvement in district heating and cooling projects.

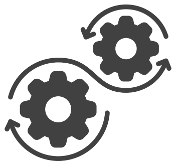
Regulatory framework

The success of DHC financial and business models hinges on the regulations in place. Here's how regulations and market design can impact DHC project financing:



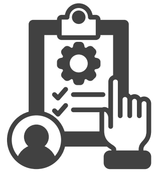
Balancing Upfront Costs and Long-Term Returns

DHC projects require significant upfront investments (high capital expenditure) with returns spread over a much longer period. Regulations need to ensure predictable returns to justify the initial investment.



Risk Management for Municipalities/Companies

Different project risks can affect municipalities and public companies implementing DHC. Robust regulations and public support mechanisms can mitigate these risks, improving project bankability. This is especially crucial for innovative technologies (like 4^{th} and 5^{th} generation DHC) that offer potential cost savings but might carry higher risks.



Incentivising Cost Reduction

Regulations that encourage cost reduction allow DHC operators to maximise infrastructure investments while minimising the burden on end-users.

Sharing Efficiency Gains with Consumers

Effective regulations ensure that cost savings and efficiency gains achieved by DHC operators are passed on to final consumers.

The current regulatory frameworks in many Countries might not be compatible with the rapid investment timeline required for DHC projects. Restrictions on equity financing, limitations on debt, and pressure to reduce operational costs can hinder crucial investments. Publicly supported financial instruments can play a vital role in overcoming these hurdles.

The "Wholly public" business model

Of the various ownership models for district energy systems, the "wholly public" business model is the most commonly used. Here, the public sector, in its role as local authority or public utility, has full ownership of the system, which gives it complete control of the project and makes it possible to deliver broader social objectives, such as environmental outcomes and the alleviation of fuel poverty through tariff control..

In this model, the city takes on most of the risk associated with the investment: consolidated urban areas develop such projects via a public utility, and the low return is spread across other projects that have higher IRRs. Projects in new urban areas can be developed by creating a "Special Purpose Vehicle" (SPV) or subsidiary (such as a new public utility) to reduce the administrative burden on the local authority, with governance typically overseen by a board of directors that represents the local authority. Shifting to a subsidiary can provide additional benefits, including limiting the city's financial liability, increasing the flexibility and speed of decisions, and offering greater transparency and a more commercial operation. The local authority can outsource the technical design and construction (and sometimes operation) of the project to reduce risk related to the delivery cost and time frame.

To the extent that a district heating and cooling system contributes to a city's strategic objectives – such as reducing carbon emissions, improving resilience or energy security, or providing affordable heat supply – projects often leverage the city's cash reserves and/or public debt raised based on the balance sheet of the local authority. The lower interest rate of public debt is why many proponents of district heating and cooling systems argue that cities can (and should) be investing in this way and why several district energy models are locally led.

> ***"For district energy systems it is sometimes difficult to compete with cheap natural gas; we are always in competition with fossil fuels. It is important to have planning commitments, other than free market dynamics."***

Per Alex Sørensen, DHC consultant at PlanEnergi

The "Public/Private" business model

When a district heating and cooling system's project has a return on investment that will attract the private sector, a "public/private" model can be adopted. Here, the local authority is willing to carry some risk and has a desire to exercise some control, but it also seeks private sector participation to bring in expertise and/or private capital. A challenge with such projects is ensuring that all parties have a clear, aligned vision of what the objectives are and how they will be achieved.

This public-private collaboration can take several forms:

Public/Private joint venture

Typically involves the creation of an SPV, with ownership split between the public and private sector. Risk and investments are shared between partners. The public sector can mitigate some risks by committing to long-term contracts and can deal with regulatory barriers to project development. The private sector typically takes care of the de-sign, construction and operation, while on occasion also benefiting from connection to the network.

The presence of the public sector often means access to additional funding sources such as development bank loans. Governance is typically via a board of directors appointed by each project partner, with board representation reflecting the ownership split between the public/private sectors.

Concession contract

In this model, the public authority often makes the first steps of the district heating and cooling project, and then tenders it to the private sector. The Energy Service Company (ESCO) or utility with the concession (private sector or public-private) bears completely the risks of designing, building and operating the district energy system. The presence of the local authority as de-signer of the concession contract is likely to mitigate many of the risks associated with gaining project approvals. The ESCO may be limited in the tariffs it can charge due to local competition or by contractual levels set to avoid monopolization of energy distribution.

A concession model is particularly applicable for retrofit projects in towns and cities where public streets are used for network routes and where residential, institutional and commercial buildings are connected. The concession provides the option of the city getting back a project after the concession period.

Community-owned not-for-profit or cooperative

A municipality may wish to establish a district energy system as a mutual, community-owned not-for profit or cooperative. This is most wide-spread in countries where district heating has a strong administrative support, and end users are obliged to connect to networks. In these cases, district heating operators are legally obliged to be not-for-profit and are therefore either cooperative, mutual or municipal companies.

The "Private" business model

If a local authority has a proposed district energy project with a high return on investment but at the same time it favours a low risk tolerance and a relatively low desire for control, it may be able to attract interest from private sector companies.

This does not mean that the local authority is removed from the project; many successful privately-owned district energy systems still have arms-length local authority involvement. For example, the local authority may have been the original project proponent and/or it could still attract financing and grants for the project; it needs to provide the planning and regulatory support in all cases, and may help with any connections deemed socially optimal that are too high risk for the private sector. It could also develop initiatives that encourage social or environmental objectives, such as mechanisms that support low-carbon generation.

In a purely private model, risk is carried by the private company, although the company could enter into a Joint Cooperation Agreement (JCA) with the local authority to mitigate risks in planning or expansion, or to encourage connection of demand through planning policies. This is often called a Strategic Partnership Model. In return, the local authority may benefit from reduced tariffs, profit sharing, connection of customers with higher credit risk (who are more likely to be in fuel poverty), and other social or environmental objectives

Financing is provided by the private sector company. The private sector company may require a capital contribution in the form of a connection charge for any public buildings connected to the network. Local or national authorities may be able to attract international loans or grants for the project.

Combined models for DHC and heat pumps

The inclusion of heat pumps into district energy networks offers significant benefits in terms of cost and emissions reduction. This integration can enhance the security and flexibility of heat supply while helping to stabilise the energy market.

However, several barriers exist that hinder the adoption of these systems. Factors such as knowledge gaps, economic challenges, and process complexities make the combined use of heat pumps and district heating systems difficult. For instance, energy pricing often fails to consider the high investment costs associated with these solutions, as well as their externalities, which significantly influence decision-making. Moreover, the involvement of multiple companies across various stages of the value chain leads to fragmentation. Additionally, public procurement processes typically do not prioritise district heating and heat pumps as viable solutions for Heating and Cooling needs.

In practice, district heating (DH) and heat pumps (HP) are often employed in a complementary manner. DH is utilized when HP alone cannot meet building requirements, while HPs efficiently utilize surplus energy generated by intermittent renewable energy sources. Two main approaches have emerged to enable DH companies to optimise their operations and customer relations while incorporating HPs into their systems.

The first approach involves implementing a dynamic pricing model, which ties energy prices to the hourly marginal cost of heat production in the DH system. Under this model, customers own the HP, DH substations, and the building heating system. The DH company provides a bundled solution where both HP and DH are connected to a control interface. This interface receives signals determining which energy source to use based on factors such as electricity prices, building heat demand, HP performance, and DH price.

The second approach is the performance contract model, where the DH company gains full control over the HP, regardless of ownership. The customers' HP becomes an integral part of the DH production plan, with a fixed fee payment ensuring a guaranteed indoor temperature. Essentially, for this model to be profitable, the internal cost for DH must be lower than what clients pay. Unlike the connected product model, the performance contract model requires DH company responsibility to extend to the internal radiator system.

GOVERNANCE AND REGULATION

GOVERNANCE AND REGULATION

Role of municipalities and decision-making processes

The quote above gives a good idea of the important role municipalities have when fostering and facilitating district energy systems, as they can be present in most of the key enabling capacities of the district energy chain: regulating, planning (in particular heat zoning), facilitating, providing, consuming, (...).

That is why it is so important for municipalities to envision the future energy system of their city, including interactions with other assets (built stock condition, electricity grid); that way, both planners, suppliers, financers and customers will have a framework to effectively implement these kinds of systems and to limit associated risks.

One of the first steps for cities to achieve this envisioning goal is to develop heat zoning plans which allow to obtain a comprehensive assessment of roll-out potential of district heating and cooling systems. These planning tools can serve as a guide on where it is most feasible or convenient to develop district heating or cooling networks, the available supply and demand, and help making early decisions on the technologies to deploy and use.

In addition to heat zoning plans, the following activities can be performed by the municipality to foster district heating and cooling:

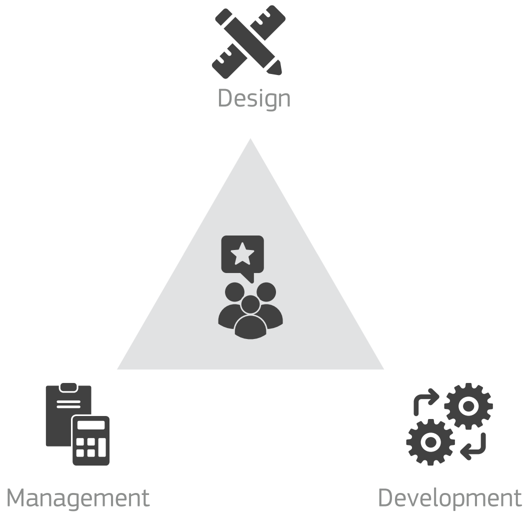
- **Procurement** and infrastructure **investments.**
- Facilitating **financing and taxing** incentives.
- **Capacity building** of planners, developers, owners, suppliers, industry, investors.
- Stakeholders' and citizens' **awareness raising campaigns.**
- Energy **commercialisation** (at district level) for public purpose.
- **Act as an agent of change, promoting and disseminating DHC initiatives in public infrastructures.**

> ***"Local governments are uniquely positioned to advance district energy systems in their various capacities: as planners and regulators, as facilitators of finance, as role models and advocates, and as large consumers of energy and providers of infrastructure and services"***

UN Environment Programme, 2015

During the design, deployment and operation of the district heating and cooling network, the governance model will largely depend on the business model adopted (see Business Models and Finance section).

Regarding the core **decision-making team from planning to implementation stages**, experts in district energy systems deployment recommend looking for a **compact group of stakeholders**, so the team involved in design, development and management tasks can **work closely together**. In most cases, the municipality must be on board and participate in all decisions. In parallel to this compact group, an effective engagement with key local stakeholders and citizens' representatives must be a priority, as described in the section on "Societal and user aspects" on page 12.



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EU and cities' district energy strategies

The recast EU Energy Efficiency Directive, which was adopted in July 2023, includes a new obligation requiring Member States to ensure that municipalities with over 45 000 inhabitants prepare local heating and cooling plans. This is a significant step towards decarbonising the heating and cooling sector in European cities.

During the next few years, the challenge will be to develop these local plans (according to 2022 figures from Eurostat, 75% of heating and cooling is still generated from fossil fuels while only 25% is generated from renewable energy), through ambitious objectives and taking into account that national contexts still present major differences.

As of January 2024, heat planning is mandatory in Germany for municipalities with more than 100 000 inhabitants, which must draw a heat plan up by 30 June 2026. Moreover, in the state of Baden-Württemberg, heat planning has been mandatory since 2020. In Flanders (Belgium), all municipalities must have heat zoning plans by 2025.

Regarding the possible targets, some generic examples are presented below, and a selection of exemplary EU frontrunner city goals is included thereafter (table on the next page):

- **Expansion of the district energy system** (amount of homes, offices, shops, etc. connected to the system)
- **Interconnection of segregated district energy networks** through transmission pipes
- Share of total **greenhouse gas reduction target** to be met by district energy systems in the city
- Share of electricity/ heating/ cooling **capacity or consumption provided by district energy** systems
- Share of **local government's energy usage** that should come from district energy systems
- Share of **renewables or waste heat** to be used in district energy systems
- Percentage of **energy efficiency** increase due to district energy use
- **Replacement of existing** individual heating/ cooling **systems**

District heating network at Kortrijk Weide, Belgium ©Agata Smok

Table 1 District energy goals in cities (UNEP)[6]

City	District energy goals
Dortmund, Germany	Developing a Heat and Energy Plan Switching district heating system to utilise industrial waste heat as a primary energy source Increased energy efficiency and lower emissions
Islington, UK	Heat Master Plan identifies 14 priority clusters for development Heat Network Zoning implementation from 2025 likely to cover 95% of the borough Sub regional Local Area Energy Planning (LAEP) in 2024 to inform local LAEP that will likely establish district energy as the most cost-efficient solution for 95% + of the borough Exploring opportunities for public-private, or private led partnerships through the Net Zero Neighbourhood program and opportunities for joint ventures or concession models
Mannheim	District heating plan in place Climate neutral heat supply by 2040 Transition/exit from fossil fuels and shift towards renewable energy sources The district heating plan creates planning and investment security for companies and citizens

Dortmund, Germany ©Arian, Unsplash
Islington, UK ©Tak-Kei Wong Unsplash
Mannheim, Germany ©Justus Menke

6 District Energy in Cities. Unlocking the Potential of Energy Efficiency and Renewable Energy (UNEP)

How to get started in my city?

Key questions and summary of reflections

As a starting point for cities, there are some key questions to be answered. A thorough reflection on them can lead to a successful implementation.

Regarding sustainable and/or renewable heat/cold resources; what is the local potential?[7]

A city- or region-wide mapping of available and planned energy resources must be performed. Depending on the specific context of each city, there will be better conditions for some energy sources than others; sun, wind, geothermal, waste heat/cold, etc. In this city-mapping, it is key to look at the amount and temperature level of the resources to make an informed decision. As renewable energy sources often benefit from substantial open space for their production, it is recommended to consider the regional energy potential rather than the strictly urban energy production potential. Hereby an optimal energy exchange between the city and its hinterland can be achieved. A similar argument holds for the recuperation of waste heat and/or valuable waste streams, e.g. from industrial and agricultural complexes adjacent to the city. In addition, other aspects need to be carefully assessed. Urban density and energy intensity of the areas to be served, along with consideration of building uses, potential synergies and need for cooling are key aspects to early decision making.

7 Check "Technical specifications" on page 14

Is it feasible?

It is important to quantify the thermal energy demand and to assess which specific system can fit it better. The first step to start a new district heating or cooling network can be to get all large consumers on board (swimming pools, hospitals, offices, supermarkets, large residential complexes...), as this will significantly ease the process. Involving them in a working group can be a good choice, to exchange advantages and needs of the system and its customers. Identifying these opportunities in a setup coordinated by the municipality can be very supportive; even more so if this is connected to urban planning procedures, and to local heat zoning planning (see above) in particular.

Is it financially viable?[8]

Without a business case, it will be very difficult for an initiative to succeed. What are the distances from source to consumers? What kind of distribution is going to be used? Does the urban characteristics allow profitability? (E.g. urban density, heat demand density, corresponding urban retrofit strategies). The high initial investments and the long-term commitments needed will test the viability of each operation (ROI + risk/control degree by local authority).

Considering an implementation time-frame in cities, there is a substantial difference between new grids and extensions of existing grids. Regarding new grids in new developments, where everything must be implemented from zero, the process can take at least 3 years to be in operation. However, in existing grids, an expansion project can take even less than a year, depending on the particularities of the project. In both cases, these timeframes can be extended mainly due to bureaucratic, financial and technical obstacles.

8 Check "Business models and finance" on page 28

Let’s get started! Key steps in developing a district energy system

In case those pre-reflections are leading the city to develop district energy systems, the following steps will guide the preparation of a welcoming environment for this kind of project, according to the specific city characteristics.

Key Steps in developing a District Energy System[9]

1.	Assess **existing** energy and climate policy objectives, strategies and targets, and **identify catalysis**
2.	**Strengthen** or develop the institutional **multi-stakeholder coordination framework**
3.	**Integrate** district energy into national and/or local **energy strategy and planning**
4.	**Map local energy** demand and evaluate local energy resources (Heat Planning)
5.	Determine relevant **policy design considerations**
6.	Carry out project **pre-feasibility and viability**
7.	Develop **business plan**
8.	Analyse **procurement** options
9.	Facilitate **finance**
10.	Set measurable, reportable and verifiable **project indicators**

De Voerman realizes a neutral district heating/cooling grid on neighbourhood scale, fed with thermal energy from a main drinking water pipe in Anzegem, Belgium. Further reading: De Voerman Anzegem

9 District Energy in Cities. Unlocking the Potential of Energy Efficiency and Renewable Energy (UNEP)

GENERAL LESSONS LEARNED

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GENERAL LESSONS LEARNED

LESSONS LEARNED

- District heating plays an important role as cities identify its ability to deliver secure, clean and cost-effective municipal heating supply.

- District cooling has a huge potential to reduce the increasing electricity demand and the rejection of waste heat into the urban environment linked to massive use of air conditioning and chillers. This can be a factor in reducing the Urban Heat Island effect.[10] Moreover, this potentially translates into cost savings by avoiding backup systems or over sizing the electricity capacity; common measures adopted for the prevention of blackouts.

10 The urban heat island (UHI) is a phenomenon whereby urbanized areas record higher temperatures than the surrounding, outlying areas because buildings, roads and other urban infrastructure absorb and re-emit the sun's heat more than natural landscapes like vegetation and water bodies. Local waste heat emissions in urban areas add to this UHI effect.

- The low supply and return temperatures of modern district heating and cooling systems allow the integration of local, distributed heat and cold sources as well as waste heat and cold reutilisation. This can lead to significant energy savings and a drastic reduction of primary energy use and CO_2 emissions. Such strategy however requires that the building stock is prepared for receiving the low temperature heating, respectively the high temperature cooling. Integrated urban planning and the development of proper heat zoning plans shall first guarantee a coherent energy strategy at the level of districts, the city and its hinterland. But this also implies that proper building retrofit strategies are put in place.

LESSONS LEARNED

District heating and cooling can, through interaction with the electricity grid, enable higher penetration of intermittent renewable energy sources, such as wind and solar from the electricity system, using large-scale heat pumps, CHP plants and short and long-term thermal storage.

Digital technologies make the energy system smarter, more efficient, reliable, and boost the integration of more renewables into the system. Technologies such as IoT, artificial intelligence and machine learning enable district energy systems to fully optimise their heat sources and network operation and flexibility while empowering the end consumer.

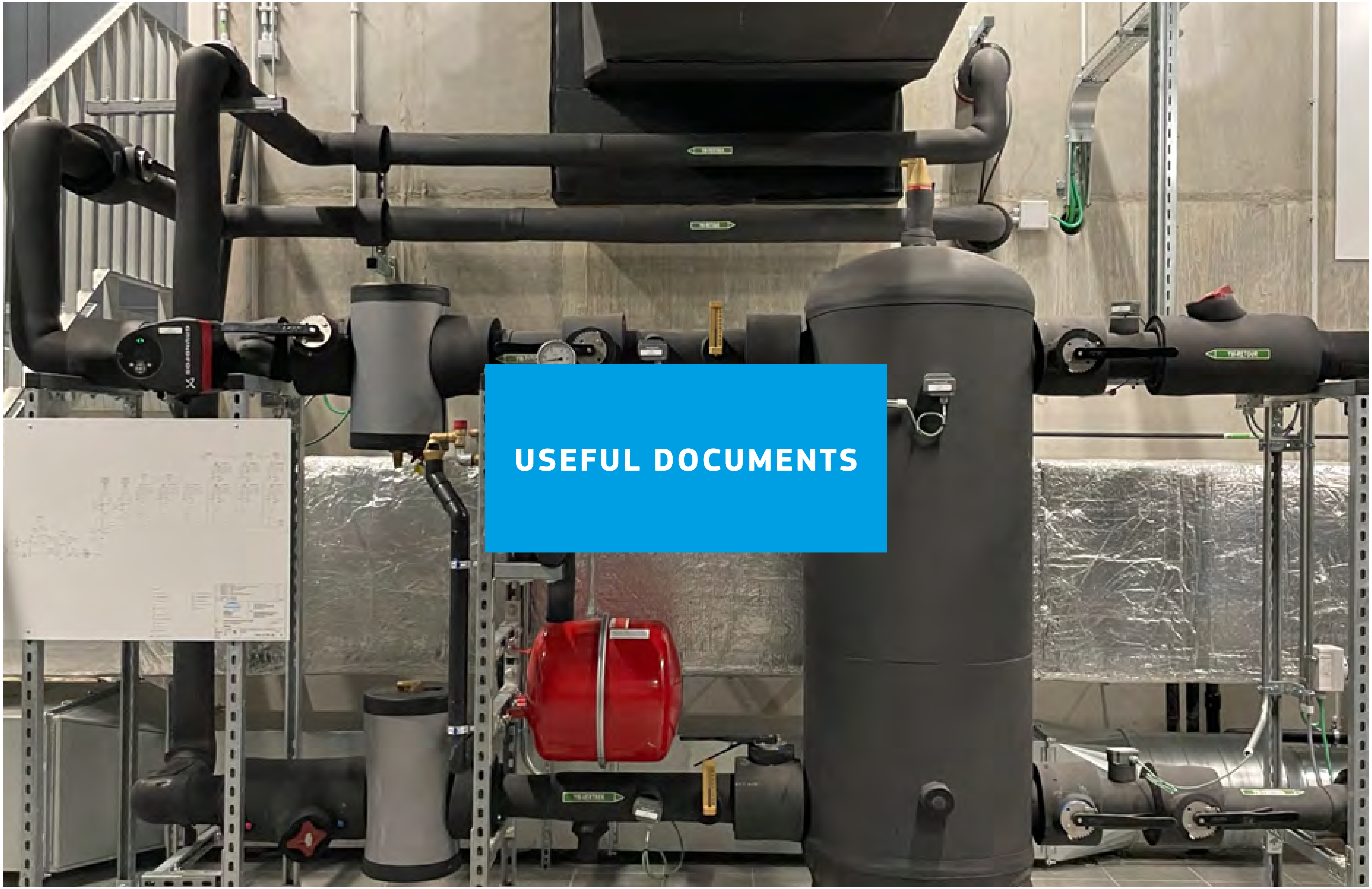
LESSONS LEARNED

- Local governments are uniquely positioned to advance district energy systems in their various capacities: as planners and regulators, as facilitators of finance, as role models and advocates, and as large consumers of energy and providers of infrastructure and services.

- The ideal business model for a DHC project is defined by the degree of ownership that the public sector desires over the project and by its expected revenue (ROI), resulting in 3 basic paradigms – wholly public / hybrid public-private / private. The local administration should have a higher involvement if the district energy project contributes to local objectives, such as local climate action plans.

- The integration of energy planning into urban planning procedures can pave the way to DHC deployment; including heat zoning, DHC requirements in master planning, fostering denser urban areas, setting up urban retrofit strategies, combining mixed uses in the building sector and the like. In many instances there is still a long way to go in this integration process.

USEFUL DOCUMENTS



The city of Kortrijk installed a pilot district heating network at Kortrijk Weide, as a nucleus for further extensions in the city ©Agata Smok

USEFUL DOCUMENTS

Relevant documents and tools

The following discusses the potential of district energy systems in cities to enhance energy efficiency and integrate renewable energy sources. It explores how these systems can reduce greenhouse gas emissions, lower energy costs, and support sustainable urban development. The report provides case studies, best practices, and policy recommendations to encourage the adoption of district energy solutions worldwide:

- District Energy in Cities. Unlocking the Potential of Energy Efficiency and Renewable Energy (UNEP)

The website of Euroheat & Power focuses on promoting district heating and cooling in Europe. It provides information on the benefits, technologies, policies, and best practices related to district energy systems. The site serves as a resource for industry professionals, policymakers, and the public, aiming to support the transition to sustainable, efficient, and resilient energy solutions across European cities and communities:

- EuroHeat&Power - The international network for district energy, promoting sustainable heating and cooling in Europe and beyond

The website of the Danish Energy Agency's Technology Catalogues provides comprehensive information on energy technologies. It offers detailed descriptions, performance data, cost estimates, and future projections for a variety of energy technologies. The catalogues are designed to support policymakers, energy planners, and industry stakeholders in making informed decisions about energy investments and strategies, with a focus on promoting efficient and sustainable energy solutions:

- Danish Energy Agency publications: catalogues of technology data for energy technologies

The Heat Roadmap Europe website's Peta4 section provides access to the Pan-European Thermal Atlas (Peta4). This interactive tool maps heating and cooling demand across Europe, identifying potential areas for district heating and cooling systems. It aims to support the development of efficient, low-carbon heating and cooling strategies by offering detailed spatial data and analysis, helping stakeholders make informed decisions about energy planning and infrastructure investments:

- Pan-European Thermal Atlas – Heat Roadmap Europe

The webpage for energyPRO describes it as software for modelling, analysing, and simulating complex energy projects. It supports a range of technologies including CHP plants, heat pumps, solar collectors, and more. The software provides detailed technical and financial analysis, optimizing energy systems with cross-sectional considerations for electricity and thermal energy. It offers user-friendly interfaces and reports, accepted by major financial institutions like the World Bank.

- EnergyPRO modelling software
- EnergyPLAN software

Projects and initiatives

SmartEnCity (SCC1)

- DC supported by residual heat in Tartu
- DH network in existing areas in Vitoria-Gasteiz

Smarter Together (SCC1)

- Redensification of DH and Integration of data center waste heat into DH in Vienna

Remourban (SCC1)

- DH using low-temperature return heating in Nottingham
- Biomass DH in existing areas in Valladolid

GrowSmarter (SCC1)

- Smart local thermal grids and virtual analysis on DH and DC rings in Barcelona

MySmartLife (SCC1)

- DH optimisation through renewables and storage system in Helsinki
- DH monitoring thorough decision-making tool in Nantes

Replicate (SCC1)

- New DH systems in San Sebastian and Bristol

Other research projects

- Act!onHeat - Accelerating the use of strategic heating and cooling planning in cities
- THUNDER - THermochemical storage Utilization eNabling Data centre seasonal Energy Recovery
- TEMPO project
- D2Grids, rolling out 5th generation district heating and cooling
- PUSH-IT project
- KeepWarm - Improving the performance of district heating systems in Central and Eastern Europe

HeatRoadmap.eu is a platform focused on providing information and resources related to heat planning and energy efficiency initiatives, likely aimed at policymakers, researchers, and professionals in the field of sustainable energy:

- Heat Roadmap Europe
- IEA Task 55 SHC: Integrating Large Scale Solar Heating & Cooling Systems in District Heating & Cooling Networks
- IEA Task 68 SHC: Efficient Solar District Heating Systems
- CELSIUS – Combined efficient large scale integrated urban systems
- CELSIUS INITIATIVE, CELSIUS Toolbox

The STORM project website is dedicated to the STORM District Heating and Cooling (DHC) network project. It focuses on developing and implementing an innovative controller to optimize the operation of district heating and cooling networks:

- STORM - Self-organising Thermal Operational Resource Management
- H-DisNet - Intelligent Hybrid Thermo-Chemical District Networks
- CoolHeating - Market uptake of small modular renewable DH and DC grids for communities
- progRESsHEAT - Supporting progress of renewable energies for heating and cooling in the EU on a local level
- FLEXYNETS - 5th generation, Low temperature, high EXergY DH and DC NETworkS
- INDIGO - New generation of Intelligent Efficient District Cooling systems

The INDEAL Project typically involves research and development efforts aimed at improving district heating and cooling systems, focusing on enhancing energy efficiency and integrating renewable energy sources:

- InDeal – Innovative Technology for DH and DC
- E-HUB – Energy-Hub for residential and commercial districts and transport
- Micro- TRIGENERATION
- Heat4Cool - Smart building retrofitting complemented by solar assisted heat pumps integrated within a self-correcting intelligent building energy management system
- COOL DH - Cool ways of using low grade Heat Sources from Cooling and Surplus Heat for heating of Energy Efficient Buildings with new Low Temperature District Heating Solutions
- Planheat - Integrated tool for empowering public authorities in the development of sustainable plans for low carbon heating and cooling

HotMaps Project is dedicated to a research or initiative focused on mapping and analysing the potential of sustainable heating and cooling solutions across Europe, likely aiming to support policymakers, planners, and stakeholders in the transition to low-carbon energy systems. It likely provides tools, data, and resources to facilitate informed decision-making in urban planning and energy policy:

- **HotMaps - Heating and Cooling: Open Source Tool for Mapping and Planning of Energy Systems**

The website for the Thermos Project is dedicated to a research or initiative focused on advancing sustainable heating and cooling technologies and practices in urban environments, likely aiming to reduce energy consumption and greenhouse gas emissions. It provides information, tools, and resources to support the implementation of efficient thermal energy systems in cities:

- **THERMOS - Thermal Energy Resource Modelling and Optimisation System**

Website related to the “PITAGORAS” project, which involves research or initiatives in the field of education and technology. The project aims to develop innovative teaching methods or tools to enhance learning experiences in these areas:

- **PITAGORAS – Sustainable Urban Planning with innovative and low-energy thermal and power generation from residual and renewable sources**

The Sinfonia Smart Cities website outlines the Sinfonia project, which focuses on demonstrating and promoting energy-efficient renovation and sustainable energy solutions in European cities:

- **Sinfonia – Smart initiatives of cities fully committed to invest in advanced large-scaled energy solutions**

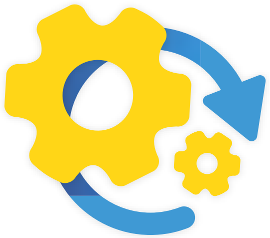
The Smart City-Ready website is dedicated to the Smart City-Ready project, which aims to support cities in becoming more energy-efficient and sustainable. It provides information on tools, methodologies, and best practices to help cities integrate smart energy solutions, focusing on the role of district heating and cooling systems. The site offers resources for city planners, policymakers, and other stakeholders to enhance urban energy management and promote the transition to smart, low-carbon cities:

- **READY project**

Smart Cities Marketplace

The Smart Cities Marketplace is a major market-changing initiative supported by the European Commission bringing together cities, industries, SMEs, investors, researchers and other smart city actors.

The Marketplace offers insight into European smart city good practice, allowing you to explore which approach might fit your smart city project. Discover our digital brochure here.



Matchmaking

The Smart Cities Marketplace offers services and events for both cities and investors on creating and finding bankable smart city proposals by using our Investor Network and publishing calls for projects.

Investor network

Call for Applications – Matchmaking Services

Project finance masterclass

Focus and Discussion groups

Focus groups are collaborations actively working on a commonly identified challenge related to the transition to smart cities.

Discussion groups are fora where the participants can exchange experiences, co-operate, support, and discuss a specific theme.

Focus and Discussion groups

Community

Scalable Cities

A city-led initiative providing large-scale, long-term support for the cities and projects involved in the Horizon 2020 Smart Cities and Communities project.

Scalable Cities

DISTRICT HEATING AND COOLING
SOLUTION BOOKLET

Smart Cities Marketplace 2024

The Smart Cities Marketplace is managed by the European Commission Directorate-General for Energy