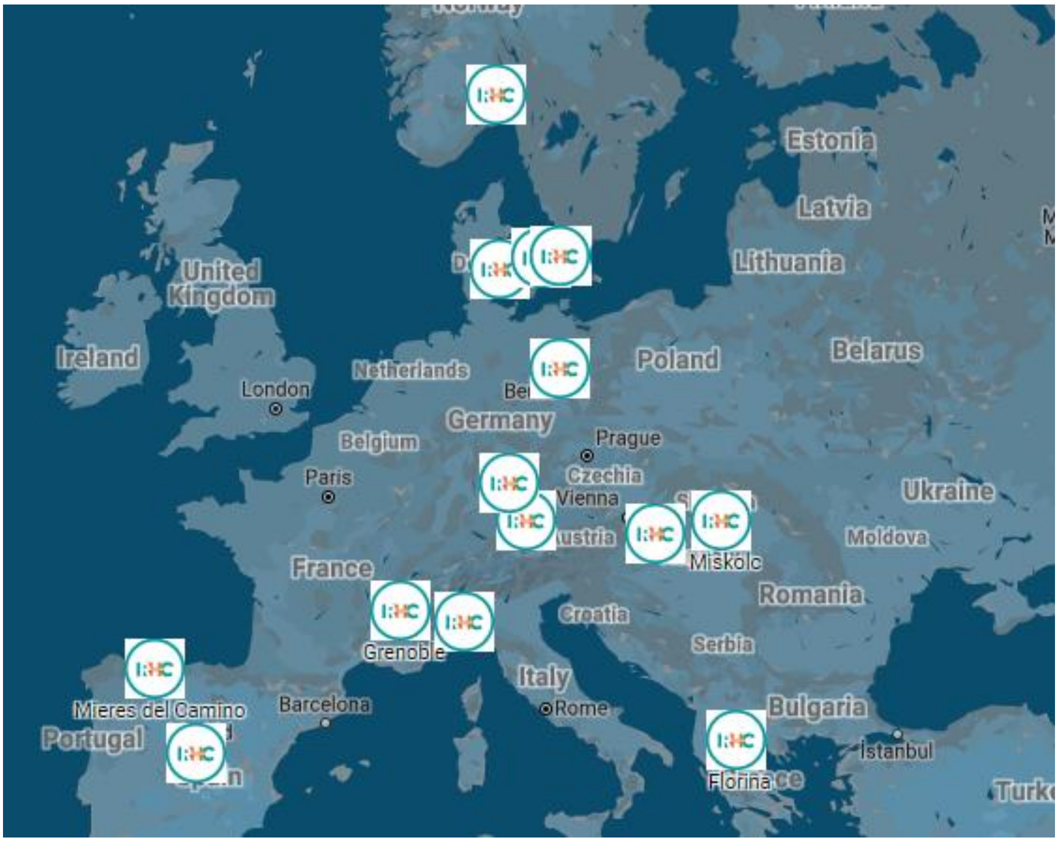
Renewable Heating & Cooling

European Technology and Innovation Platform

100% Renewable Energy Districts:

2050 Vision



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Prepared by: Sofia Lettenbichler and Alessandro Provaggi (DHC+ Technology Platform c/o Euroheat & Power) and HWG Districts members

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ABBREVIATIONS

4GDH: 4th generation district heating

CAPEX: Capital expenditures

CHP: Combined Heat and Power

CTES: Compact thermal energy storage

DC: District Cooling

DH: District Heating

DHC: District Heating and Cooling

EC: European Commission

EU: European Union

GHG: Greenhouse gas

GW: Gigawatt

GWh: Gigawatt hour

H&C: Heating and Cooling

ha: hectare

HFC: Hydrofluorocarbons

ICT: Information and Communications Technology

LTDH: Low temperature district heating

MW: Megawatt

MWh: Megawatt hour

NPCM: Nano phase change material

O&M: Operation and maintenance

OPEX: Operating expenses

p2h: Power to heat

PCM: Phase change material

PED: Positive Energy District

PV: Photovoltaic

RD&I: Research, Development and Innovation

RES: Renewable(s)

REC: Recoverable

RHC ETIP: European Technology and Innovation Platform on Renewable Heating and Cooling

TRL: Technology Readiness Level

VAT: Value Added Tax

PARTNERS

EUREC: the Association of European Renewable Energy Research Centre

AEBIOM: Association Européenne pour la Biomasse

EGEC: European Energy Council

EHP: Euroheat & Power

ESTIF: European Solar Industry Federtation

EHPA: European Heat Pump Association

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Introduction

The energy landscape is shaped by cities. 72% of the European population (EU28) lives in urban areas - defined as cities, towns and suburbs. Globally, cities account for about two-thirds of primary energy demand and 70% of total energy-related carbon dioxide (CO2) emissions. The energy and carbon footprint of urban areas will increase with urbanisation and the growing economic activity of urban citizens. The decarbonisation of cities and city districts presents an imperative and an obvious area of priority. Districts, in particular, have specific opportunities to drive the decarbonization efforts as they know best about their local needs and locally available infrastructure and resources.

Ambition

Europe has the ambition to become a global role model in integrated, innovative solutions for the planning, deployment, operation and replication of Positive Energy Districts (PED) with the aim to have at least 100 Positive Energy Districts by 2025.

Within the regional energy system, a 100% renewable energy district enables the use of locally produced renewable energy by offering optimal flexibility, in managing consumption and providing storage capacities to the regional energy system on demand. Deploying solutions for DHC in districts with high energy density will offer efficiency gains through easier thermal storage integration, savings, risk sharing and, subsequently, increase attractiveness to commercial investors. It is therefore, an example of energy efficiency and circular economy at local level. Active thermal energy and storage management will allow for balancing and optimisation, demand response and reduced curtailment of electricity from renewable energy sources, and district-level self-consumption of thermal and electric energy.

A 100% renewable energy district makes optimal use of locally available renewable energy sources and waste heat. For historic reasons, cities and towns developed along rivers, lakes and seashores which provide access to environmental heat. All these sources make high and low-temperature renewable energy available, and their usage is highly replicable because it is accessible right where it is needed. In order to use local sources, municipalities, energy utilities and the industry have to collaborate across sectors.

In the vast majority of urban areas, district energy is technically and economically more viable than individual-based solutions, and can be 100% decarbonised through the use of renewables (biomass, including residues, solar thermal and geothermal energy), waste and environmental heat, and fossil-free cogeneration. Fossil-fuel boilers need to be completely phased out.

Local leadership

In 2050, the subsidiarity principle will be applied to the European energy systems. Monitoring and control of generation, conversion, storage and consumption in all energy sectors will be done in an integrated, highly automated, fully-trusted way, within regions which are dynamically sized and cell-based. The subsidiarity principle means that energy systems are operated in such a way that actions are taken locally and regionally (at the most immediate level). Only actions that cannot be handled locally are handled at the next level. While this is a macro-trend for the whole energy sector, the inherently local nature of heating and cooling supply means cities must play a leading role in developing and implementing strategies for their decarbonization.

The local energy systems will have the inherent ability to balance themselves through the integrated and automatically monitored and controlled use of all parts of the supply and demand side along with self-learning mechanisms and the empowerment of citizens. The capacity of local governments to implement effective sustainable energy policies should be increased, including extending the legislative power of regions where appropriate. Cities can and must show leadership in this area and decisions have to be taken locally. Cities' efforts will only have the desired impact if they are complemented by compatible regulatory frameworks and investment environments established at European and national level. Regional, national governments and the EU should, however, define targets and provide clear direction for the local actors. How to enable energy leadership at local level but at the same time coordinate the different local dimensions over the entire continent from a system and market perspective, remains an important RD&I topic to be solved well before 2050.

Planning tools and methodologies that are specific to the district heating and cooling sector are necessary in order to coherently model, analyse, and design the heating and cooling systems as an integral part of the entire energy system. This is an important part of developing pathways and strategic plans of cities that contribute to a decarbonised energy system for the future. Heat planning should be compulsory for cities and municipalities. These additional obligations should be complemented by regional and national support schemes. In addition, cities should be allowed to carry out zoning planning by themselves in order to empower them to implement the changes they need.

The biggest challenges are not technological: Bringing robust, reliable and sustainable heating and cooling to the heart of our cities is far more than a vague aspiration - it is a basic and entirely achievable necessity. By exploiting the potential of existing technologies such as efficient district heating and cooling networks, renewable energies, waste and environmental heat, and fossil-free cogeneration, we can move away from dependence on imported fossil fuels and towards reliance on the mix of renewables and waste heat and cold that are available in every community across Europe. Innovation priorities need to have strong financial, market uptake measures and citizens' engagement dimension to let renewable solutions replace fossil fuel-based solutions. In doing so, we can make an orderly and highly cost-effective transition to a full decarbonized heating and cooling sector by 2050, creating smarter, greener and, more livable cities along the way.

Energy integration as driver for circular economy renewables and further efficiency

It is vital to take an integrated approach towards the energy systems planning, development and operations across all energy infrastructures. Buildings and district systems will work together to optimise temperature levels, time of use and storage opportunities to minimise total life cycle cost (emissions and cost), recording input from usage patterns, weather predictions, and future utility costs. Transport and other IT usage predictions will be considered. Furthermore, appropriate cross-sectoral software interfaces need to be established to achieve interoperability. Energy efficiency and renewable energies should be maximised and the synergies between them optimized by tapping into existing local resources and innovative technologies.

An integrated approach implies better exploiting the potential of thermal storage. Energy storage will be key in the future energy transition. The cost-effective potential of all types of renewable energy storage, including combined storage, long-term and seasonal solutions, should be identified and unlocked. Beyond traditional heat storage, cooling storage will provide flexibility and improve efficiency in cooling production at the same time that as reducing the electricity peaks and providing a smart and cheaper way to store electricity. This will prove crucial in a system which includes a high share of variable renewable energy and, in the future, it is expected that thermal storage will be a cost-effective solution.

The most typical applications of latent thermal energy storage for cooling are using ice tanks. However, to charge the storage tanks, the chillers will have to operate at very low efficiency due to the low water temperature at the outlet. The new applications use other materials that change-phase to more appropriate temperatures. Phase-change materials, such as paraffins and hydrated salts, can be used at temperature levels more suitable for cooling, contributing to increasing the energy efficiency and the share of renewable energies such as geothermal, aerothermal and solar energy for cooling.

Non-Technological innovation priorities

Citizen engagement and participation

A modernised H&C sector empowers local communities, small businesses and citizens, giving each citizen the possibility to take part in the energy transition as a consumer, worker, investor or even producer as a member of a community that relies on decarbonised heat supply.

It is important to enhance fact-based and proactive communication, since social media (possibly including fake news) represents a growing challenge for municipal/regional planning processes:

- A transparent and inclusive framework for public participation in decision-making processes (public consultation procedures and consultation meetings) should/must be provided.
- Enthusiastic community members, once identified, often function well if engaged as local/regional "ambassadors" from the beginning.
- Initiatives for local/regional communities to increase and sustain acceptance should be developed (i.e. creating relatable "win-win" solutions).
- Strategies to handle local/regional initiatives that seek to prevent progress in decarbonisation.

Energy communities can be the entry point for a change in the traditional business model in which operators own the assets, to a new one in which citizens take up this role. Community-based projects should be prioritized under the premise that community-owned solutions have to do better in terms of decarbonisation and air quality improvement than other available solutions. As investment plays a key role in final energy prices when using renewables, this new approach will provide better prices for end users while operators can concentrate their efforts in what really is their core business (managing the production and distribution of energy). Many small and medium low-temperature DHC networks will emerge, sharing energy between them so digital tools must be created to manage this new scenario.

Customers can assume both the role of energy consumers and producers. Business schemes will be developed with energy users as a focal point, trying to gather social acceptance and triggering the wide adoption of the solutions implemented within the framework of this project. The financial benefits for prosumers should be structured to reflect the needs of the overall system.

Policies and price signals should encourage flexible interactions for prosumers to help balance energy grids instead of simply maximising the owners' self-consumption.

Financial innovations

The current business model of the DHC sector where a solid customer base is needed before an investment is made does not work well and does not contribute to scaling up renewable and efficient heating and cooling solutions rapidly. Extending the ability of cities to generate revenue and access financing at lower cost will support their efforts to undertake sustainable energy programmes and infrastructure projects.

There is a need to develop business models that shift from the conventional approach of "heat as a commodity" to "heat as a service", in order to examine the investment appetite of institutional investors. There is a need for business models and tariffs that benefit consumers who want to contribute to demand-side management. To scale the investments up, innovative approaches must be found so as to enable investors to understand how an efficient contract can be built and how the investment risk shifts from low investment and high operation cost to high investment and low operation cost for renewable energy usage.

In the framework of an increasing lack of financing, crowdfunding can have a major role in adding new sources of finance and raising capital from diffused investors. The solution is often characterized by a greater engagement of end-users.

New skills

New skills will be required from energy planners and heating system providers and installers as energy efficiency, automation, IT solutions and services will become prevalent in the heating & cooling sector. A mix of skills from different disciplines, including control engineering, energy engineering and computer science will be required. In general, the skills needed will be based on raising the efficiency-levels of DHC networks, meaning that tools and measures for optimization have to be managed. In addition, for cities and districts the new position of energy managers will emerge, whose role will be central to driving the energy transition: the role will combine both energy planning and public policy skills.

A shift is also needed in terms of business logic, moving from large production plants and distribution networks to decentralized, efficient production and distribution of heating and cooling. For district energy providers and policy makers this necessitates a shift in terms of understanding the new demand and needs of the customers who will also be prosumers.

Technological innovation priorities

District energy/ thermal storage innovation priorities for Integrated energy systems

RES integration at regional and local levels

Develop and/or demonstrate technologies, systems and solutions to match system temperatures with locally available low-carbon sources, including the set-up of new networks with low and very low supply temperatures and the reduction of the temperatures in existing networks. Solutions should enable buildings to operate with low supply and/or return temperatures in a cost-effective and sustainable manner. Further on, the system design/operation should be adapted to the lower temperatures, including the integration of heat pumps, cooling options and storage. Suitable business models involving building owners and end customers should also be addressed.

Develop and demonstrate technologies, systems and solutions that make it possible to efficiently provide, host and utilise high shares of renewables, up to and beyond 100% in the local or regional supply, by following a holistic view on the energy system, linking different energy domains (electricity, heat/cold, green gas, mobility) at different scales while considering system, market and organisational aspects, allowing for the optimal use of renewable energy sources and recovered energy.

Develop methodologies, tools and technologies that enable local energy communities to operate multi-dimensional energy systems that optimally integrate regional infrastructures and facilities. These shall also enable local energy communities to actively contribute to the energy markets and to the resilience, stability and flexibility of the overall system. Solutions have to consider the layers: Technology (cyber-physical), market and adoption in order to increase efficiency above the established European target and improve quality of supply over the established level.

Flexibility

Coupling the electrical and thermal grids plus, energy storage will result in a significant reduction of electrical peaks, maximize the use of renewable energy sources and improve the efficiency of the whole energy supply. Sector coupling through the integration of power-to-heat (p2h) technologies can also be integrated in the overall strategies to reduce curtailment and network enforcement

Develop and/or demonstrate technologies, systems and solutions to increase the short (hours to days) and long term (weeks to months) flexibility of district heating networks. The aim is to minimise the discrepancy between the load and supply profiles of alternative heat sources (incl. power-to-heat) and, in turn, reduce the use of fossil fuels in peak load and winter time and avoid supply competition during summer. Solutions should improve the cost–benefit ratio of storage options and/ or improve the customer side integration where smart buildings learn and offer flexibility to existing customers.

Digitalisation innovation for Sector Coupling & Integration of Multiple Sources

Further research and testing of technical and operational modelling, simulation and optimization of multi energy technologies and systems is required to identify the technological and systemic constraints. Technical interoperability between DHC technologies, automation and electricity market standards to enable private equipment that contributes to sector coupling (e.g. heat pumps, EV loading stations, etc.) to be seamlessly integrated into a wider system of systems.

ICT systems for DH sector coupling should improve in the following fields: real time supervision of energy flow at building and system level, intraday forecasting for demand, source prices and flexibility potential, cost competitive deployment using cloud-based systems and configuration templates, strengthening AI smart algorithms, financial and transactional systems with multiple consumers, prosumers and suppliers, virtual power plant aggregation systems adapted to DHC stakeholders, Interaction of high-level controls (energy management systems) and low-level controls operating the single technologies, distribution networks, etc.

Waste heat recovery innovation priorities

Increase the awareness and knowledge level of urban waste heat recovery among technicians, local administrators, investors and industry sectors which may provide waste heat including: data centre, sewage and service sector operators.

Integrate and evaluate waste heat recovery solutions in both national and local energy strategies and identify where it is possible to develop heat networks and thermal storage facilities near sources of excess heat. Promote the integration of waste heat recovery solutions into local and regional energy efficiency planning.

Promote technical integrated solution to optimize the cost of using waste heat for DHC.

Upscale advanced, modular and replicable solutions enabling the recovery and reuse of waste heat available at the urban level from different sectors (services, transport and other urban infrastructures). Develop cooling networks from waste heat, based in absorption and adsorption chillers.

Scale-up successful contractual arrangements and new business models for the urban waste heat recovery system aimed at guaranteeing economic advantages to all the actors involved in the process.

Specific DHC innovation priorities

Multi-source District Heating integrating renewable and recovered heat sources

Develop and implement measures to integrate additional RES and REC heat sources in various sizes on existing DH networks in a cost-efficient manner. Develop and implement measures specifically targeting the combination of constant and fluctuating sources and more decentralized networks in general but particularly taking into account specific needs for: base load supply and competing base load sources, seasonal loads vis-à-vis the seasonal availability of sources, peak loads, peak availability of sources vis-à-vis the investment costs especially compared to current standard gas-fired peak boilers.

Develop suitable models for the efficient usage of close to zero cost electricity via boilers and heat pumps in combination with short and long-term storage solutions.

Develop, implement and share business models for multi-source DH networks including hybrid solutions and bidirectional connections.

4th Generation Low-Temperature DH Networks

Optimization of building heating system, to minimize the temperature levels in district heating networks. The aim of this research and innovation topic is to improve the design and the operation of the building heating system in order to be properly adjusted to the operating conditions of the 4GDH, of lower supply and return temperatures.

Improve the control of the operation of the indoor heating system in order to operate under 4GDH principles. Identify how heating systems can be adapted to the lower energy requirements after the renovation of the existing building in order to operate under 4GDH principles.

Develop technologies to ensure tap water quality even at lower heating temperatures.

Optimised solutions for non-uniform temperature district heating systems using advanced distribution solutions integrated with decentralized and/or centralized heat storage to cover simultaneously space heating a DHW using very low and low water temperature distribution.

District cooling (DC)

Develop higher temperature DC for the integration of more natural cooling and increased efficiency.

Develop specific tools that can provide more confidence and thus more openness to DC systems' deployment and use.

Development of a highly efficient and intelligent DC system based on the development of an innovative and optimized DC system Management Strategy, and the integration of predictive controllers at component level.

Digital technology priorities for DHC

It is important that the production, distribution and consumption control systems become integrated.

Production: Develop operational analysis, optimisation and predictive maintenance using AI principles.

Distribution: there are several benefits in digitalising the distribution system, relating to operational analysis, real-time control and overall efficiency of the system. Digitalising the distribution system will facilitate a more balanced energy distribution, leakage detection and minimise heat loss.

Building level: further develop the connection between operational grid optimisation and efficient heating controllers, increase the digitalisation ability of the substations with cost effective communication and data management hardware/software, develop Business models enabling grid operators to manage, and possibly own the substation. This will provide ways to develop the offer to building owners and tenants, as well as, to integrate the substation into the grid's energy system.

Consumption: enable consumers and buildings to behave better and more efficiently in the DH network. Standardizing the communication / smart metering solutions, at least the connectivity part of it. Focus more on empowering energy providers to take more responsibility instead of just visualising the data on behalf of the end-user and trust that they will change and improve. Make sure the GDPR regulation will not limit access to data or require end-user consent.

Planning and Design: Development and application of new methodologies, tools and processes allowing for integrated energy infrastructure planning which supports the day-to-day decision making process in cities, energy utilities and other decision makers (e.g. property developers) and finally leading to a socio-economic optimum and at the same time allowing for new business models (e.g. prosumer integration).

Specific Thermal Energy Storage innovations

Thermal energy storage enable the increased use of renewable and waste heat sources in energy systems and increase the flexibility of these energy systems on all scales and in multiple application fields. The main developments in technology can be subdivided into large, sensible thermal energy storage and in compact thermal energy storage technologies.

For large thermal energy storage based on sensible heat storage, like large water pit storage, the challenge is to make the storage systems suitable for a large variation in locations and for integration in a range of local or district heating and cooling systems.

Aspects for further development or improvement are: liner materials for high temperatures that have a (very) long lifetime and acceptable costs, construction techniques for large volumes, deep pit or tank storage in different geological settings, thermal insulation materials and techniques to cost-effectively lower the heat loss and improve storage performance, floating or self-carrying lid constructions to enable the use of the storage top area, optimized system integration and hydraulics and controls to optimise system performance. Important for cold storage are the development of phase change materials with working temperatures between 5 and 15 degrees C, the integration of cold storage in cooling systems and the optimization of these systems.

Several compact thermal energy storage technologies (CTES) have reached a TRL 5 to 6. Further improvement towards cost effectiveness of such systems is dependent on the parallel development of novel materials, on improving components and further developing and demonstrating systems based on the present generation of compact thermal energy storage materials.

For materials: novel material classes, like mesoporous materials or composite materials need to be further developed, testing methods need to be developed and assessed and the materials have to be integrated in the reactor components. Cost reduction is an important target for the storage materials development.

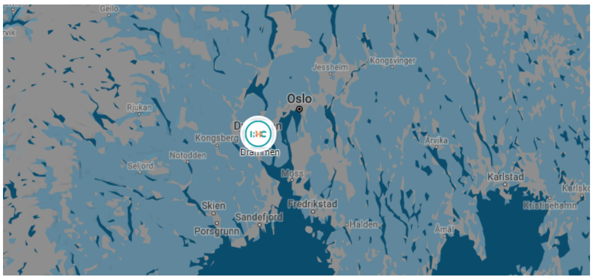
For the components: new reactor principles need to be developed and optimized, and existing heat exchanger designs need to be optimized for the storage materials.

At system level: the components need to be controlled in an optimal way, with novel sensor technologies to determine the state of charge and control strategies that take the typical characteristics of thermochemical processes into account. Furthermore, current generation CTES systems need further development towards demonstration, in order to tune the systems to the practical application situations and to find the optimal market introduction schemes for the next generation of CTES systems.

Phase-change materials, such as paraffins and hydrated salts, can be used for latent cooling storage, contributing to increase the energy efficiency and the share of renewable energies such as geothermal, aerothermal and solar energy, for cooling. The range of values most suitable for storing cold according to the most favourable charging and discharging conditions vary between about 5 ° C and 12 ° C; there are several solutions of paraffins and hydrated salts that cover this temperature range. The most traditional solutions have been based in tanks filled with water and with PCMs inside small containers with different shapes (plates, balls, cylinders). More recently, tanks have been developed, with heat exchangers in which the PCM is immersed in the exchanger and transport fluid (water) passes through the interior of the tubes. The main objectives are to reduce the volume of tanks and increase the rate of energy transfer. Some recent investigation has been done to increase the thermal conductivity of paraffins using nanoparticles (nano enhanced, NPCM) that can be useful mainly for cooling systems where the delta T in the heat changers are more limited.

100% Renewable Energy Districts Examples

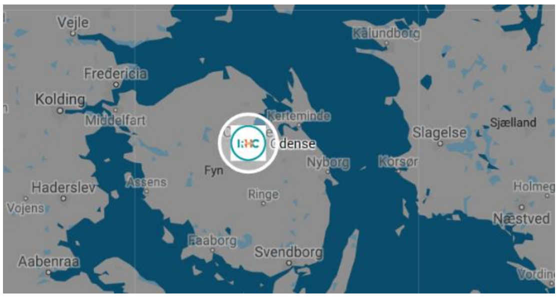
Drammen, Norway



City	Drammen
District name	Drammen
Project name	Jacobs Borchs Gate
Project status	Realised
Project start – end	2009-2012
Contact	Jon Vincent Haugen
Project website	www.df.no
Size of project area	1000m2 (energy centre)
Building structure	Existing neighbourhood
Land use (% or m^2/hectare)	City Centre
Drammen wished to upgrade their existing district heating which was a mixture of electric, biomass and gas/oil. They recognised the need to move from fossil and combustion fuels and so decided to utilize seawater as a heat source for an industrial heat pump. Also recognizing the danger of HydroFluoroCarbons (HFCs) and other synthetic working fluids they began to explore the use of ammonia.	
Goals and ambition (it must be about full decarbonisation of a district area)	A drive for both non fossil fuel and non-greenhouse gas working fluids plus maximum efficiency led to deploying ammonia fjord source heat pumps.
Is this project idea replicable in other districts of Europe? Why? Under which conditions?	Totally. Every major city is on a river or has a waste water treatment plant. Civilisation grew in proximity to rivers for reasons of food, hygiene, defence, trade and continues to this day. The rivers are in effect delivering (free of charge) the solar thermal energy that has been collected by the land. In the case of Glasgow this is a 4000 square km catchment area.
Economic Indicators/expected impact	Burning gas loses the client money. Specific financial information isn't available on sales price of heat but gas costs

	€70/MWh, biomass €50/MWh and heat pumps €10/MWh (electricity is €30/MWh).
Environmental Indicators/expected impact	Heat delivered from the heat pump is 67GWh/year, which avoid 78Gwh of gas, whilst consuming 23GWh/yr of electricity which is practically zero carbon. In the UK the same consumption would equate to 5,000 T of CO2 per annum. Gas would be 16,000 T of CO2 per annum. The working fluid being ammonia contributes practically zero CO2. Had they used HFC R134a this would have been an equivalent of 800000km of driving equivalent if the plant leaked 70kg per year.
Societal Indicators/expected impact	Hard to say as Norway is so accustomed to district heating and doesn't have a gas network. However were the buildings to use electricity their cost would be far higher.
Overall strategies of city/municipality connected with the project	Keep expanding. They also plan to utilize the waste cooling (10MW – enough for 10 soccer fields worth of data centres).
Describe strategy	N/A
Describe key steps of the process (please indicate between 5 to 10 steps)	They began deploying a district heating system many years ago and continue to offer heat at a competitive price. The key to expansion is the operation of a concession whereby buildings must connect if on the DH but don't need to buy but must be offered reasonably priced heat. So everyone wins and the network is as large as possible and still growing.
How are citizens involved in decision making process?	The facility is 50% owned by the city financial leaders and 50% owned by private investors. The price of heat is regulated and transparent. The quality or cleanliness of heat is also regulated with respect to carbon and combustion particulate hence the shift from biomass.
Describe financing aspects	As above, the facility is owned by an Energy Services Company. Profits are reinvested.
Describe business model	Make heat cleanly and cheaply and sell fairly, reinvesting in growing the network and continuing to improve the quality of the facility.
Regulatory aspects that help the project	Cleanliness and price control.
Regulatory aspects that hinder the project	None obvious.
Success factors	Biggest ammonia heat pump operating at 90C in the world.
Challenges and barriers	Keep growing, broaden supply options to include cooling.

Odense, Denmark



City	Odense
District name	Odense, Fyn
Project name	Coal phase out by 2025
Project status	Multiple projects in planning and under construction
Project start – end	2018-2025
Contact	Head of Business Development, Kim Winther
Project website	Fjernvarmefyn.dk
Size of project area	All of Odense area
Building structure	n/a
Land use (% or m²/hectare)	n/a
Fjernvarme Fyn has decided to phase out the remaining 30% coal consumption in the heat production by 2025. Already coal consumption has been reduced from ~900.000 t/y in 2010 years ago to 2-300.000 t/y today but the goal is to substitute this completely. The tools are electric heat pumps to a large extent, large heat storages, biomass boilers and electric boilers. The challenge is to carry this out without price increases for the consumers especially the greenhouse industry where heat price is an important competition faction.	
Goals and ambition (it must be about full decarbonisation of a district area)	0 coal in 2025
Is this project idea replicable in other districts of Europe? Why? Under which conditions?	Yes. We use local heat sources for our heat pumps, i.e. waste heat from data centres, industry etc. and ambient heat in sea and air.
Economic Indicators/expected impact	Minimal price increase ~5-10%
Environmental Indicators/expected impact	½-1 mio. T CO2/year
Societal Indicators/expected impact	Danish job creation (construction, technology, technology export)
Overall strategies of city/municipality connected with the project	UN sustainability targets, green city, maintain jobs in greenhouse industry, make district heating even more attractive

Describe strategy	Our overall vision is to be the preferred supplier of future heating solutions. The vision underlines that we aim to use technologies that are sustainable in the future. The targets are to phase out coal by 2025 and at the same time keep our position among the top 3 lowest district heating prices in Denmark. We believe district heating can/will be the preferred solution in Denmark as the collective solutions give synergies, gives a more efficient energy transformation (fx utilization of waste heat and surplus power production from wind energy) and makes the entire energy system more robust than with multiply individual solutions. Our strategy is to invest in a number of smaller units and not to substitute the existing coal plant 1-1. The smaller units can be multiple 10-20 MW heat pumps, a 30-50 MW biomass boiler, +50 MW electric boilers etc. The exact figures are still pending as we are developing our scenario calculations up to summer 2019.
Describe key steps of the process (please indicate between 5 to 10 steps)	2018: Strategy was formulated 2018: Scenario analysis 1.0 and 2.0 was made 2019 Q2: Analysis of new plants is being reported 2019 Q2: Scenario analysis 3.0. (several iterations) describing the optimal roadmap towards 2025 2019 Q3: Decide on first new plants to commence planning phase
How are citizens involved in decision making process?	Our 200.000 costumers are represented by our owners /board who are approving all major decision. On a daily basis the business is run by the Fjernvarme Fyn CEO and top management
Describe financing aspects	The entire coal phase out plan is expected to sum up to DKK 2 billion
Describe business model	The entire coal phase out plan is expected to sum up to DKK 2 billion
Regulatory aspects that help the project	Renewable fules are not taxed on district heating and require no carbon allowances. Hence there is an incentive to substitute the taxed coal (and gas) with renewables, where the saved taxed is an indirect substitute that can finance new investment and prices can be kept steady (to some state). Process heat costumers pays no tax so they lack incentives. Fjernvarme Fyn has secured a small subsidy from a subsidy schemes to process heat but are under a time pressure to

	realize this subsidy by 2021 as the scheme has been shut down.
Regulatory aspects that hinder the project	Tax on surplus heat No new subsidies for process heat Production of heat without power production (ie no CHP production) is the most viable solution in the future but requires an dispensation in Denmark as CHP has been preferred until now
Success factors	No coal after 2025 No (major) price increase High share of electrification (heat pumps) High utilization of local heat sources
Challenges and barriers	Heat pumps are not proven in large scale Biomass is no longer a politically accepted fuel Costumers are allowed to "cut the connection" to district heating and find an individual solution, so we need to be competitive and informative of our advantages

Windsbach (Neubaugebiet Badstraße), Germany

City	Windsbach
District name	N/A
Project name	District heating « Neubaugebiet Badstraße »
Project status	under construction
Project start – end	Start: March 2017
Contact	WÄRME.natürlich GbR Untereschenbach 13 91575 Windsbach Tel. 09871 / 65 71 53 Mail: info@waerme-natuerlich.de
Project website	www.waerme-natuerlich.de
Size of project area	About 100 1-family houses
Building structure	newly built houses
Land use (% or m²/hectare)	

The municipality of Windsbach has planned a new residential housing project, heated by district heating (DH). The project is divided into several construction phases. In total approximately 100 low energy consumption houses are planned. The total heat demand is estimated with 1000 MWh. The peak load will be about 800 kW. The aim is to supply as many houses as possible with the provided district heating. The complete heat is produced with renewable energy. Therefore biogas CHPs and one peak load biogas boiler are installed.

For the heat distribution pre-insulated pipes from ENERPIPE are installed. The dimensioning was optimized for the low energy houses, therefore heat losses are very low. Instead of standard Heat Interface units in each individual house is a new developed decentralised buffer unit installed. This helps to reduce the peak heat demand. The units are able to increase the efficiency of the heat network, while optimising the charging and reducing the return temperatures.

Goals and ambition (it must be about full decarbonisation of a district area)	Reduction of the heat losses up to 15-20% Reduction of the return temperatures to 30-35°C
Is this project idea replicable in other districts of Europe? Why? Under which conditions?	A replication is possible. Requirements are: low energy consumption houses, as much connections as possible, predominantly floor heating systems
Economic Indicators/expected impact	Economic operation of the heat grid Appropriate costs for heat for homeowners
Environmental Indicators/expected impact	The DH network is heated with renewable energy. So the CO2 emissions are very low.
Societal Indicators/expected impact	High identification through the use of Renewable Energy. Strengthening of community spirit.
Overall strategies of city/municipality connected with the project	Promotion projects for climate protection. Advertising for a sustainable and environmental friendly policy.
Describe strategy	N/A
Describe key steps of the process (please indicate between 5 to 10 steps)	N/A
How are citizens involved in decision making process?	N/A
Describe financing aspects	The conditions and prices for connection are published at the homepage, as well as the kilowatt-hour-rate and the basis rate for heat. So price-policy is very transparent.
Describe business model	The operator creates a "heat-careless-parcel" There is a flat rate for connection to the district heating network, incl. the delivery and installing of the buffer unit. The costs for heat supply are divided into a kilowatt-hour-rate, a base rate and a concession levy.
Regulatory aspects that help the project	Municipality demands renewable energy. Especially biogas is used for the CHP's and gas boilers. No gas pipe was installed in the building site.
Regulatory aspects that hinder the project	There is no need to connect to the district heating network. So homeowners have the possibility to install an alternative renewable heating system, like heat pumps or geothermal heat. So there is a risk for an economic operation of the heat network.

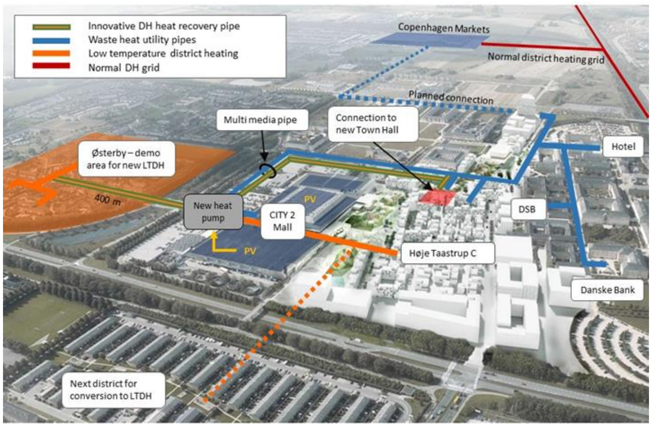
Success factors	Communication and information (events, homepage) about district heating. The heat network operator is a local farmer. Therefore the communication ways and response times are very short.
Challenges and barriers	A few homeowner have installed radiators or a combination of radiators and floor heating system, therefore the return temperature is higher than in case of a floor heating systems for the whole house. The on site installers haven't got specialised knowledge about DH. They do the planning and installing of the heating systems as usual.

Grenoble Metropolis, France

City	GRENOBLE Metropolis
District name	All the city
Project name	N/A
Project status	Ongoing
Project start – end	1970
Contact	CCIAG – Nicolas Giraud
Project website	https://www.cciag.fr/
Size of project area	Entire city
Building structure	Old and new
Land use (% or m²/hectare)	N/A
The GRENOBLE-ALPES-METROPOLIS (METRO) district heating, with its 170 km of liquid pressurized water distribution pipes, is the second largest District Heating System in France (900 GWh). The district heating is a strong part of the energy strategy of the city. Since 30 years, the city is engaged in a process to integrate renewable energy and decarbonize the network. Then CO2 emissions have drastically dropped (-60%) since 1990 to reach a minimum level (115 g/kWh) in 2017 while the RE penetration is currently about 66.5%. The integration of renewable and recovery energy accelerates and solutions are deployed to achieve a 100% RE District Heating in 2033. State of the art solutions (biomass, waste heat from incineration plant, …) are combined with innovative solution (storage, CO2 capture, smart control, …) that are under study and development with CEA research center.	
Goals and ambition (it must be about full decarbonisation of a district area)	100% RE district heating Cancel the use of fossil fuel in the DH
Is this project idea replicable in other districts of Europe? Why? Under which conditions?	YES
Economic Indicators/expected impact	Competitive price of the DH compared to other energy
Environmental Indicators/expected impact	100% RE in 2033

Societal Indicators/expected impact	Maximise local energy and satisfaction of user
Overall strategies of city/municipality connected with the project	The development of the DH and its decarbonisation is part of the directory scheme of energy of city that include all energy (gas, electricity and heat)
Describe strategy	The strategy is based on : • Integration of recovery and renewable energy : replacement of fossil fuel boiler • Densification and extension : increase or stabilize the energy delivered of the DH • Innovation: development of advanced control system and innovative components (storage,…)
Describe key steps of the process (please indicate between 5 to 10 steps)	75 % RE in 2020 85 % RE in 2022 100% RE in 2033
How are citizens involved in decision making process?	Citizens were involved in the directory scheme of energy of the city
Describe financing aspects	The investments are done by Grenoble-Alpes Metropolis and the private company CCIAG
Describe business model	The district heating is operated through a public delegation service : the private company CCIAG invests and operates the district heating for the next 15 years
Regulatory aspects that help the project	French regulation : - specific VAT on energy delivered by DH that includes at least 50% of renewable and recovery energy - classification of green and efficient district heating : obligation of new building in the area to connect to the DH - benefits in the building regulation for new buildings connected to low carbon district heating
Regulatory aspects that hinder the project	N/A
Success factors	Strong investment of the municipality and the district heating operator to develop a green District Heating
Challenges and barriers	N/A

Høje-Taastrup (Østerby) – Copenhagen region, Denmark



City	Høje-Taastrup – Copenhagen region (DK)
District name	Østerby
Project name	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 (LTDH)
Project status	Under construction
Project start – end	October 2017 – September 2021
Contact	Reto Michael Hummelshoj - RMH@cowi.com Gabriele Pesce – gp@euroheat.org
Project website	http://www.cooldh.eu/
Size of project area	The network will serves an area of terraced houses with 158 dwellings. The LTDH network will eventually be expanded in the neighbouring areas with 350 houses (36,000 m²),
Building structure	Mixed
Land use (% or m²/hectare)	36,000 m² + In Høje-Taastrup, the results of COOL DH will be used for designing a new urban development of 250,000 m²
The COOL DH project will innovate, demonstrate, evaluate and disseminate technological solutions needed to exploit and use sources of very low-grade "waste" heat for heating of energy efficient buildings via Low Temperature District Heating (LTDH) and show how the District Heating (DH) systems can be more resource efficient and more energy efficient. The demonstration covers both new developments and stepwise transition of existing areas with district heating and energy retrofitting of buildings. The COOL DH consortium consists of the utilities and municipalities of the two cities Lund (SE) and Høje-Taastrup (DK) and leading DH energy specialists as well as leading industrial manufacturers.	

Goals and ambition (it must be about full decarbonisation of a district area)	The present project on using a larger share of low-grade surplus heat and increasing system efficiency is an important step of reducing emissions even further from the present level of 98 kg/MWh CO_2 emission (2015). The surplus heat will be harvested from various sources: • Cooling machines at the CITY2 Mall that will operate on power from more than 16,358 m² PV plant with an installed capacity of 2.07 MW (the so far largest roof mounted PV plant in the Nordic Countries of Europe). • Cooling machines and cooling of servers at the Danske Bank data centre, DSB and hotels having a high cooling demand year round. At the moment in Høje-Taastrup the DH is based on 49 % fossil and the CO_2 emission factor is 98 kg/MWh (2015). Alongside a coalfired CHP-plant called Amagerværket, in the neighbouring city of Copenhagen, will undergo a transition to use biomass during the actual project period. The demonstration project in Høje-Taastrup is interlinked to the other COOL DH demo site in Lund which is totally fossil-free. The biomass waste heat freed in Sweden will supply the Danish side. This means that the COOL DH project will reduce the fossil fuel consumption in Høje-Taastrup and in Lund. The recovered waste heat of 10 GWh per year a consumer will liberate 5000 tons of biomass yearly.
Is this project idea replicable in other districts of Europe? Why? Under which conditions?	The project pays much attention to the future replication of projects results on a European and global scale, in particular with focus on countries similar to the North and Central European climate zone.
Economic Indicators/expected impact	The new LTDH supply will be tariffed according to actual costs, but is based on experience expected to be 10-25% cheaper in variable cost depending on temperature level.. The tariff will be calculated on the basis of the present DH market price, from which CAPEX and OPEX are deducted. This will define the earned margin.
Environmental Indicators/expected impact	The yearly energy saving based on recovery of low grade waste heat is estimated at 10 GWh p.a.; Each 1 MWh utilised low grade waste heat will save 1 MWh primary energy; used low grade waste heat will marginally save 300 kg CO_2 /MWh; In Høje-Taastrup the share of renewables will be increased from 51% to 90% for the served area.

Societal Indicators/expected impact	The project will contribute to reduce costs of heating supply, which means that collective DH supply can reach out further and compete with local supply based on natural gas and heat pumps, especially in areas where buildings are energy renovated or in areas where new energy efficient buildings are constructed. COOL DH will demonstrate secondary effects of efficiency improvement in operation of cooling systems that supply the low-grade heat to the LTDH systems and other quality of life improvements on reduced emissions and tertiary use reducing costs of snow clearance and increasing green season of plants in the science village area.
Overall strategies of city/municipality connected with the project	Høje-Taastrup Municipality has worked with environmental and energy policies for many years and published an updated climate plan in 2015. The municipality has committed itself to the requirements set up by the Danish society for Nature Conservation, i.e. requiring a minimum of 2 % reduction of CO_2 emissions per year on a continuous basis. Over the last ten (10) years, the municipality (geographically) has reduced its CO_2 emissions by more the 3% each year! The work with reducing the emissions derives partly from the former EU supported ECO-Life project under the Concerto initiative. This project led to a Danish project called Høje-Taastrup Going Green, supported by the Danish Energy Authority, and included investigations of the elements for this present project and the provision of legislative approvals. Høje-Taastrup is one of the most sustainable municipalities in Denmark and is the only municipality that has received support to demonstrate the implementation of an accelerated transition to a fossil free future in a cost effective way. The district heating supply in Høje-Taastrup is getting greener and greener every year. In 2015, the supply consisted of 51 % fossil free energy from biomasses, the renewable part of waste, solar, geothermal energy etc.
Describe strategy	In Høje-Taastrup, the results of COOL DH will be used for designing a new urban development of 250,000 m² with all facilities including homes for 3,000 new inhabitants. The name of this development is "Nærheden", and the LTDH system will fully serve the district. In addition, existing settlements of multifamily blocks are facing deep energy refurbishments and in connection with this, the heating systems will be converted to LTDH district by district.

	Furthermore, the new town hall, new residential buildings (social housing) and new and existing offices in Høje-Taastrup C (downtown) will also be connected to the LTDH system.
Describe key steps of the process (please indicate between 5 to 10 steps)	N/A
How are citizens involved in decision making process?	The District Heating company "Høje Taastrup Fjernvarme" is in charge of the implementation of LTDH. The utility was founded in 1992 and is owned by the consumers as a cooperative. Generally the public authorities pay a lot of attention to the citizens acknowledgement about the development of the project's works through a constant communication activity.
Describe financing aspects	The project will contribute to reduced costs of heating supply, which means that DH networks can be expanded further and the DH supply can compete with local supply based on natural gas and heat pumps; this applies especially in areas where buildings are renovated or in areas where new energy efficient buildings are constructed. The cost savings derive from the low marginal cost of purchasing low-grade energy. By connecting to larger DH systems, it will further be possible to export excess energy during the summer to pre-heat the return of the larger DH system. To encourage the consumers to modify their installations for LTDH supply, the COOL DH project will offer a new tailored beneficial tariff structure.
Describe business model	One task of the project is dedicated to the searching for the most suitable business model including terms for new LTDH tariff promoting energy efficiency, flexibility in supply options and ensure low return temperature, since this is vital for an efficient performance of the waste heat recovery. The business plan looks into new possible price models and contract boundaries, where the utility may own and operate substations including possible heat pump and main pipes in the building, and ensure regular inspections and heat supply at competitive cost.
Regulatory aspects that help the project	The project proposal will be approved by the authorities based on calculation of societal benefits excluding taxes and fees but including value of environmental externalities.
Regulatory aspects that hinder the project	The project will investigate all the legislative and regulatory frameworks able to support or hinder the use of surplus heat in Denmark. The analysis is still being implemented.

Success factors	The project is one of the most innovative in the field of DH and the framework in which is being implemented is already demonstrated at large-scale. The whole project is a best practice in term of share of RES and rate of CO_2 neutrality.
Challenges and barriers	Proposed concepts do not show technical and economic viability; Variations in heat supply

Lund (Brunnshög), Sweden

City	Lund (SE)
District name	Brunnshög
Project name	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 (LTDH)
Project status	Under construction
Project start – end	October 2017 – September 2021
Contact	Reto Michael Hummelshoj - RMH@cowi.com Göran Strandberg Goran.Strandberg@kraftringen.se
Project website	http://www.cooldh.eu/
Size of project area	World's largest LTDH network
Building structure	Newly built / Existing neighbourhood / Mixed
Land use (% or m²/hectare)	100 ha.
The COOL DH project will innovate, demonstrate, evaluate and disseminate technological solutions needed to exploit and utilise sources of very low-grade "waste" heat for heating of energy efficient buildings via Low Temperature District Heating (LTDH) and show how the District Heating (DH) systems can be more resource efficient and more energy efficient. The demonstration covers both new developments and stepwise transition of existing areas with district heating and energy retrofitting of buildings. The COOL DH consortium consists of the utilities and municipalities of the two cities Lund (SE) and Høje-Taastrup (DK) and leading DH energy specialists as well as leading industrial manufacturers.	
Goals and ambition (it must be about full decarbonisation of a district area)	Brunnshög district area will host the research facilities of MAX IV and European Spallation Source, ESS and Science Village Scandinavia. The main objective is to use the surplus heat from these research centers to increase the decarbonisation of the whole district heating network of Lund. In particular the project addresses use of low-grade heat sources by focusing on the huge amounts of low temperature surplus

	heat that is available from cooling of these facilities. Moreover, the buildings are powered by CO_2 neutral sources as it to a large extend is based on Wind power & Hydro power. The project addresses the use of these low-grade heat to heat buildings with high energy efficiency that can use the energy at very low temperatures i.e. <40oC mean temperature (5th Generation DH) for space heating combined with decentral temperature topping to 45-50oC for the part used for preparation of DHW using renewable energy sources. The houses served are designed to have a primary energy consumption of 40-45 kWh/m² p.a. The project will also show how existing buildings in Lund after energy refurbishment can adopt to LTDH enabling a district by district to convert to LTDH.
Is this project idea replicable in other districts of Europe? Why? Under which conditions?	The solutions demonstrated are generically usable at all sites where low-grade heat is available. The COOL DH concept is demonstrated in relative large scale already, in the initial phase. Moreover, COOL DH has a large built-in replicability potential and the solutions can widely be replicated in North and Central Europe. In Sweden there are 396 DH utilities. They all have areas that can be converted to. Also in Central and Eastern Europe, the potential is significant especially in areas with upcoming new DH systems for low energy settlements and districts with deep energy renovation.
Economic Indicators/expected impact	The new LTDH supply will be tariffed according to actual costs, but is based on experience expected to be 10-25% cheaper in variable cost depending on temperature level. But CAPEX will be higher. The cost of the surplus heat is zero or even (as there is a saved cost of not having to operate a heat sink at the source). The project will be calculated on basis of the present DH market price, from which CAP-EX and O&M-EX for the total at the consumers are subtracted. This will define the earned margin. The earned margin will serve the DH users collectively leading to a competitive lower overall cost than for the present DH system, which represents best available solution existing today.
Environmental Indicators/expected impact	The yearly energy saving based on recovery of low grade waste heat is estimated at 10 GWh p.a.; Each 1 MWh used low grade waste heat will save 1 MWh primary energy; used low grade waste heat will marginally save 300 kg CO_2 /MWh;

	In Lund the share of renewables will be increased from 98% to 100%.
Societal Indicators/expected impact	The project will contribute to reduce costs of heating supply, which means that collective DH supply can reach out further and compete with local supply based on natural gas and heat pumps, especially in areas where buildings are energy renovated or in areas where new energy efficient buildings are constructed. COOL DH will demonstrate secondary effects of efficiency improvement in operation of cooling systems that supply the low-grade heat to the LTDH systems and other quality of life improvements on reduced emissions and tertiary use reducing costs of snow clearance and increasing green season of plants in the science village area.
Overall strategies of city/municipality connected with the project	The municipality has a political goal to reduce its environmental and climate impact substantially. Between the years of 1990 – 2020 Lund will decrease the total amount of GHG emissions by 50 %. In 2050 the GHG emissions should be nearly zero. The municipality has six overarching goal areas where one is to decrease its environmental and climate impact substantially. In this way, the expansion of the city can take place without increasing the GHG emissions and the biomass presently used in the district heating system will be released to replace fossil fuels where this is used today. As in many other Swedish cities, district heating started up in the 1950's and the district heating system now covers almost the entire city. The main heat production unit is a large scale biofuel based CHP facility. Other important production units are a large scale geothermal system, a heat pump for recovery of heat from sewage water, district cooling heat pumps and other renewable energy sources. Kraftringen has the ambition to be completely free from fossil fuels in all heat production, and the production in Lund is fossil-fuel-free already today. Expansion of the city will call for more non-fossil energy sources to be integrated and used in the system such as low-grade waste heat.
Describe strategy	The sustainability framework for the municipality of Lund is called Lundaeko. This framework is structured into eight different focus areas: Involvement, sustainable consumption, clean water and clean air, minimizing climate impact, decreasing chemical stress on the environment, sustainable city, climate change adaptation and biological diversity.

Describe key steps of the process (please indicate between 5 to 10 steps)	The different focus areas are taken into account in the yearly planning process of the municipality. The yearly progress is described and evaluated in a sustainability report and is processed in an evaluation with top city management and decisionmakers. Internal and external revues are performed on a regular basis.
How are citizens involved in decision making process?	The development of the area is being implemented by the Lund-owned utility Kraftringen. Lund municipality is one of the main partner and sponsor of the project. Generally the public authorities pay a lot of attention to the citizens acknowledgement about the development of the project's works through a constant communication activity. Specific tasks of the project focus on the relation with the citizens.
Describe financing aspects	Soft loans over 50 years are used for building works. The housing companies finance the RES supply for the selected demo blocks. The public utility including 3rd parties finances the part of costs not covered by EC grant. The project will contribute to reduce costs of heating supply, which means that collective DH supply can reach out further and compete with local supply based on natural gas and heat pumps, especially in areas where buildings are energy renovated or in areas where new energy efficient buildings are constructed. The cost savings derive from the low marginal cost of purchasing low-grade energy.
Describe business model	One task of the project is dedicated to the searching for the most suitable business model including terms for new LTDH tariff promoting energy efficiency, flexibility in supply options and ensure low return temperature, since this is vital for an efficient performance of the waste heat recovery. The business plan looks into new possible price models and contract boundaries, where the utility may own and operate substations including possible heat pump and main pipes in the building, and ensure regular inspections and heat supply at competitive cost.
Regulatory aspects that help the project	The project proposal will be approved by the authorities based on calculation of societal benefits excluding taxes and fees but including value of environmental externalities
Regulatory aspects that hinder the project	The Swedish heating sector, including district heating, is unregulated.
Success factors	The unregulated sector results in a competitive market. The economic feasibility of this project therefore depends on cost

	awareness combined with a successful marketing/selling strategy.
Challenges and barriers	The unregulated market means sometimes heavy competition. Establishing district heating infrastructure in a new city development results in planning problems regarding the exact location of the piping network, since the roads haven't been planned in detail in all parts of the area.

Lund (Medicon Village), Sweden

City	Lund, Sweden
District name	Medicon Village
Project name	Medicon Village
Project status	under construction and partially realized
Project start – end	EON: 2017 - 2020
Contact	Nilton Chan / Sonny Strömberg
Project website	http://ectogrid.com/use-cases/medicon-village
Size of project area	Connecting and supplying heating and cooling to the building in the new Life Science Research Park development. The project at Medicon Village is supported by the Swedish Energy Agency.
Building structure	Newly built / Existing neighbourhood / Mixed
Land use (% or m²/hectare)	more than 80,000m2 office space, 40,000 m2 laboratory space and 12,000m2 residential buildings space.

Medicon Village in Lund was setup by the Mats Paulsson's foundation for Research, Innovation and Societal Development, to house more than 1600 persons in organizations dedicated to improve people´s health and lives. After the current expansion, it will consist of some 140.000m2 with ~15 GWh/year heat and 5 GWh/year chill demands. The ectogrid™ by EON at Medicon Village will connect 15 commercial and residential buildings with different heating and cooling needs.

This cutting-edge technology for tomorrow's sustainable cities connects customers with different thermal needs and utilizes waste heating and cooling between buildings, further increasing the efficiency of the energy system. The ectogrid™ has the potential to balance as much as 11 GWh of the current 10 GWh heating and 4 GWh cooling. This means the solution will use as little as 3 GWh of supplied energy, a reduction of 78.5% of the energy supply. The customer in Medicon Village will see their energy prices reduced by ca. 20%.

Goals and ambition (it must be about full decarbonisation of a district area)	Medicon Village expects major energy gains - it estimates it can reduce the amount of energy used per year to cover its heating and cooling needs from 16 GWh to 4-5 GWh by balancing energy flows within and between its properties. There are plans to complement these efforts with solar power

	on the large roof surfaces to make the area even more sustainable. The ability to circulate, reuse and share the energy within the buildings fits the mindset of Medicon Village's tenants who are committed to research and innovation in life sciences, and have strong desire to reduce the environmental footprint of the area as far as possible.
Is this project idea replicable in other districts of Europe? Why? Under which conditions?	YES ideally for a mixed-use development where there are both heating and cooling requirements. The energy solution can apply to both existing (build on to the existing infrastructure) and new districts.
Economic Indicators/expected impact	~20 % reduction of energy costs
Environmental Indicators/expected impact	~75% reduction on supplied energy compared to conventional heating and cooling systems With the ambition to have 100% local renewable electricity on site, it can be truly zero-emission energy system
Societal Indicators/expected impact	The previously restricted pharmaceutical company facility is opened up for mixed use facilities where citizens, students, office workers share the space, allowing increased integration of different social groups
Overall strategies of city/municipality connected with the project	The sustainability agenda is highly important for the city in all development and daily operations.
Describe strategy	The city strategy is to increase the density of existing city areas in order to grow the city with minimal impact on valuable surrounding agriculture land. The city has also high ambitions for sustainable energy solutions where the ability of the ectogrid™ system to make use of low temperature surplus heat is of great value.
Describe key steps of the process (please indicate between 5 to 10 steps)	2012: AstraZeneca hand over the keys to Medicon Village 2012 onwards: about 70 players have moved in comprising 570 people 2013: Lund University moves 200 researchers to Medicon Village 2015: Start of EON involvement in development and deployment of Ectogrid solution 2017: Agreement for ectogrid™ signed 2018: First buildings connected to ectogrid™

	2020: ectogrid™ for Medicon Village is finalized, including for the new built buildings
How are citizens involved in decision making process?	The planning process is highly transparent and open for all citizens to follow and the citizens are also asked for input on city development projects
Describe financing aspects	Due to the high efficiency of the ectogrid™ system the main components of the new energy infrastructure is commercially viable and financed by the customer. As ectogrid™ for Medicon Village is a demonstration project, there are some additional financial risks and development of technical features that have been supported by the Swedish Energy Agency.
Describe business model	In General, 2 business models: 1) Good Neighbor™ Energy Partnership Agreement with Building owners (Customer X) • Customer X and E.ON enters in to a framework partnership agreement. • Customer X and E.ON agrees on a specific site, which will be an appendix to the framework agreement. • E.ON creates the PPP with the city and the energy customers. • E.ON invests, builds and operates the system. • (Customer X may choose to co-invest but does not need to be active) • Customer X and E.ON shares the profits 50/50 after the investment is recovered. 2) Good Citizen™ Energy Delivery Agreement with Con/prosumers • Contract specifies terms and conditions for delivery of surplus energy • Energy price and local commercial specifications • Local site specific terms and conditions • Local technical specifications
Regulatory aspects that help the project	Motivate and support city scale sustainable energy solution on national and local levels. The City provides the necessary permits and connections to public owned sites/buildings
Regulatory aspects that hinder the project	The sharing of energy on commercial terms between different organizations is to some extent hindered by the

	current regulations. For Medicon Village it is handled by one party responsible for the overall commercial set up and the energy balance of the system, with no financial transactions between the organizations related to the exchange of heating/cooling.
Success factors	The collaboration between E.ON and Medicon Village originated in Future by Lund, Lund Municipality's Vinnova-funded platform. The platform brings together over 60 participants from companies, municipalities and businesses to work with smart and sustainable cities. Within the group, different collaborations are being created to find new solutions and innovations that have not been possible for a single actor. To the estate developers, ectogrid is superior to other solutions such as district heating because it balances energy needs sustainably with low investment costs. To the city, save costs on heating and cooling, ectogrid is more advanced than classic district heating because it is more sustainable and lower in operating costs.
Challenges and barriers	Ongoing site development, the lead time for customer discussions to connections and the fluctuation of energy demands have impact to the design of ectogrid and its energy management system for optimum energy saving and efficiency gains.

Florina, Region of Western Macedonia, Greece

City	Florina – Amyntaio
District name	Region of Western Macedonia
Project name	District Heating Municipal Company of Amyntaio (DETEPA), Greece – Building of a new biomass plant to cover thermal needs
Project status	Under construction
Project start – end	2/10/2018 – 2/02/2020 (16 months)
Contact	Dr. N. Margaritis, Dr. P. Grammelis, E. Karampinis
Project website	https://www.district-energy.gr/en/energy-en/energy-technologies-en/district-heating-en/district-heating-of-aminteo http://detepa.gr/dhca
Size of project area	1,850 connected buildings and 2,500 dwellings
Building structure	Existing buildings of villages of Amyntaio, Levaia, Filotas
Land use (% or m²/hectare)	~58.000 m2
The core of the investment program for the DH system of Amyntaio is the installation of a new biomass combustion plant to serve Amyndeon's existing district heating system as well as its future extensions. The thermal energy production unit, the implementation of which has been launched, is a combustion of biomass with a small amount of lignite. It has a total capacity of 30 MW (2x15MW) and will cover the thermal needs of the existing district heating network in the villages of Amyntaion, Filotas, and Levaia as well as future thermal needs. The contract for the implementation of the project was signed on 2/10/2018 with the contractor HELECTOR SA.	
Goals and ambition (it must be about full decarbonisation of a district area)	To cover the thermal needs of the existing district heating network in the villages of Amyntaion, Filotas, and Levaia as well as future thermal needs. The existing district heating network is now utilizing the waste heat from lignite thermal power station of Amyntaio (PPC) which is expected to close by 2021.

Is this project idea replicable in other districts of Europe? Why? Under which conditions?	Applicable to high temperature networks
Economic Indicators/expected impact	Citizens of above villages will continue to have access to cheap district heating (in relation to use of heating oil devices)
Environmental Indicators/expected impact	Buildings of above villages will continue not to pollute the environment through the use of separate heating devices (oil boilers, wood stoves, fireplaces etc)
Societal Indicators/expected impact	New jobs are expected in the organization of biomass supply chain in the area
Overall strategies of city/municipality connected with the project	To expand the network to nearby villages (Xino nero, Sotiras)
Describe strategy	Purchase new funding opportunities (EU and national)
Describe key steps of the process (please indicate between 5 to 10 steps)	N/A
How are citizens involved in decision making process?	Workshops organized in the area regarding district heating from biomass
Describe financing aspects	The project envisages the construction of two thermal power plants with biomass of a total installed capacity of 30 MWth (2x15MW). The project cost is projected to amount to € 14.57 million including VAT and is financed (55%) by European Cohesion Policy funds through the NSRF (National Strategic Reference Framework) 2014-2020". The Special Development Program of the Region of West Macedonia is also contributing to the financing of the project with a capital grant of € 1.5 million. The project fully complies with the provisions of Directive 2012/27 / EU on Energy Efficiency (L.4422 / 2015) as an efficient district heating system, since it uses more than 50% renewable energy sources (RES).
Describe business model	Amount of funding >> 6.3 million Municipality of Amyntaio own contribution >> 1.9 million Regional Authority of Florina >> 1.5 million Loan from District heating company >> 2 million
Regulatory aspects that help the project	Funding for using RES in district heating systems

Regulatory aspects that hinder the project	N/A
Success factors	Willingness of Municipality to keep heating cheaply its citizens
Challenges and barriers	Significant biomass quantities required on yearly basis. Cost effective sourcing of biomass required in order to keep district heating cost at low level. Efforts needed to develop local biomass supply chains from agricultural and forest residues. Estimated required quantity: 11,700 tones/year (industry pellet) or 12,800 tones/year (corn residues)

Móstoles (Polígono Regordoño), Madrid, Spain

<table>
<tr><td>City</td><td>Móstoles (Madrid)</td></tr>
<tr><td>District name</td><td>Polígono Regordoño</td></tr>
<tr><td>Project name</td><td>Móstoles Ecoenergías</td></tr>
<tr><td>Project status</td><td>Realized (in operation)</td></tr>
<tr><td>Project start – end</td><td>15/04/2015 - Undefined</td></tr>
<tr><td>Contact</td><td>Raúl González Alcorlo; raul.gonzalez@veolia.com</td></tr>
<tr><td>Project website</td><td>N/A</td></tr>
<tr><td>Size of project area</td><td>N/A</td></tr>
<tr><td>Building structure</td><td>Existing neighbourhood</td></tr>
<tr><td>Land use (% or m²/hectare)</td><td>N/A</td></tr>
<tr><td colspan="2">Heating Network for the supply of heating and DHW to 7,200 homes with biomass: The Móstoles Ecoenergía District Heating is a project developed to promote a heat network in the city of Móstoles, located in the southwest of Madrid and with a population of more than 200,000 inhabitants. Móstoles District Heating is Spain's largest and most ambitious biomass-based district heating plant project, which in its first phase serves 3,000 homes, and is being expanded to 7,000 homes.</td></tr>
<tr><td>Goals and ambition (it must be about full decarbonisation of a district area)</td><td>Replace the current coal, diesel and natural gas boiler rooms of 7,200 homes with a heating system with renewable energies, and avoid the emission of 18,000Tn of CO2 per year. There are currently 2,664 homes connected to which 18 GWh/year of energy is supplied, with a reduction in emissions of nearly 9,000 tCO2/year</td></tr>
<tr><td>Is this project idea replicable in other districts of Europe? Why? Under which conditions?</td><td>The idea is easily replicable to other areas, as long as there is a high population density to provide heat or cold with as little infrastructure as possible.</td></tr>
</table>

Economic Indicators/expected impact	Investment - 4.8 M€ Current annual turnover - 2 M€ Current supplied biomass - 9,000 tons/year
Environmental Indicators/expected impact	Current CO2 emission reduction - 9.000 tCO2/year (2,664 homes) Expected reduction with 7.200 homes - 18.000 tCO2/year
Societal Indicators/expected impact	The installation of a heating network with biomass represents a change of concept with respect to the traditional systems that we use to heat our homes. It is a clear sample that alternative, economic and sustainable methods exist, without penalizing our comfort or well-being.
Overall strategies of city/municipality connected with the project	Concession (75 years) of a plot of land owned by the Municipality of Móstoles for the construction and operation of a thermal power station and urban heat network with solar thermal energy and biomass support (District Heating). For this kind of project, it is essential to have the support of the City Council to facilitate the administrative procedures to make this type of project a reality. In addition, town councils benefit directly from the benefits of using clean, sustainable and green technologies in the municipalities themselves, reducing environmental pollution in cities and improving air quality.
Describe strategy	See below
Describe key steps of the process (please indicate between 5 to 10 steps)	1 - Locate an area that meets the necessary requirements for the implementation of the project (high population density, obsolete heating systems, use of fossil fuels such as coal and diesel). 2 - Commercial development of the heating network with future clients who support the project. 3 - Contracted the minimum volume of clients to develop the project; seek economic financing and technological companies for the development of construction, operation and maintenance. 4 - Execution of the works and start-up of the installation. 5 - Guaranteeing the supply of energy over time, carrying out a correct operation of the network, adequate maintenance and establishing a back-up system that guarantees supply in any circumstance.
How are citizens involved in decision making process?	Citizens are an essential component for the development of district heating projects. There are many zones and areas

	where individualised heating systems (individual boiler) are considered to be the most suitable systems to ensure comfort at a contained cost. It requires a major effort on the part of public administrations and private companies to promote the use of heat networks as efficient heat supply systems. It is so important for citizens that the support or not of this type of technology is the difference between whether carrying out projects of these characteristics or not.
Describe financing aspects	There are mainly three distinct costs: • Investment –The initial cost is high and it has an amortisation period of around 20 years. Reducing investment costs is essential in many cases to ensure the viability of the project, so it is recommended to adjust the initial investment to the initial demand of the project. • O&M - This is the recurring cost of the installation, once the heating network is up and running. It contains all the necessary costs to carry out the correct maintenance of the installation. • Fuel supply and electricity consumption - These are two costs directly related to the energy demand of the plant. Their cost is directly related to the performance of the installation, which makes it essential to have the installation in perfect operating conditions.
Describe business model	Móstoles ecoenergías tries to give solutions to several existing problems in Móstoles. It offers a heating and DHW system with renewable energy without investment costs for the neighbours. It allows them to have a modern and efficient heating system without added costs for the communities. This also permits many communities with obsolete boiler rooms, high maintenance costs for having exceeded their useful life, and low efficiency, to change into an efficient system, without maintenance costs and with a stable price throughout the contract.
Regulatory aspects that help the project	The rebate of highly energy-efficient homes with tax reductions provides an appropriate legal framework to encourage the use of new technologies that have an impact on the good of all.

Regulatory aspects that hinder the project	It is necessary to carry out rigorous inspections of deficient heating systems. Central heating systems with low performance, without maintenance and with high levels of pollution shouldn't be allowed.
Success factors	The main factor is the support of this type of project on the part of citizenship. It is necessary to provide real projects that offer alternative solutions within the current tariffs of the systems it seeks to replace and, make a commitment to education and awareness of the importance of changing our habits of energy consumption by other different models.
Challenges and barriers	N/A

Mieres (Barredo), Asturias, Spain

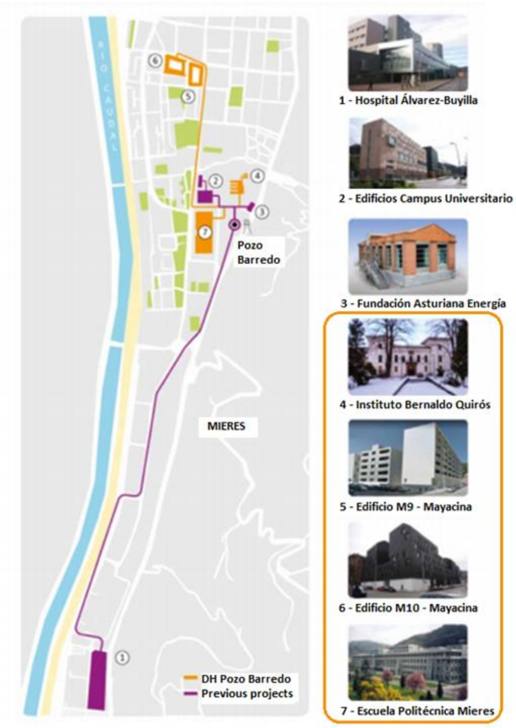


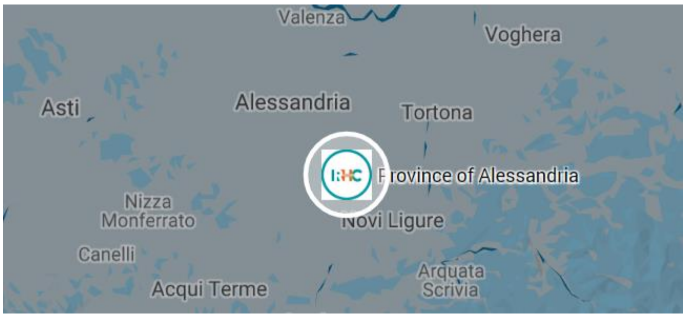
Figure 1: District Heating network in Mieres, Asturias (Orange: DH Pozo Barredo project; Purple: Previous projects).

City	Mieres (Asturias)
District name	District Heating Barredo
Project name	District Heating Pozo Barredo
Project status	Realized
Project start – end	14-12-2017 / 30-04-2019
Contact	Juan Enrique Álvarez Areces; jenriquea@hunosa.es
Project website	http://www.aulahunosa.es/red-de-calor-mieres
Size of project area	1 km2
Building structure	Existing neighbourhood
Land use (% or m²/hectare)	35% (criteria of percentage of the district affected for FEDER grant)

Taking advantage of the experience accumulated in recent years by the Hunosa Group in the installation and maintenance of geothermal facilities based on the use of mine water, it was proposed to carry out a project to create an urban heat network in the municipality of Mieres. This network starts from Pozo Barredo and serves the Polytechnic School of Mieres (EPM), the secondary school Bernaldo de Quirós (IBQ) and a group of buildings, located in the Vasco-Mayacina area, which has a total of 248 dwellings.	
Goals and ambition (it must be about full decarbonisation of a district area)	This project involves a total of 4 buildings with a heating volume of 170,065.30 m3 for a nominal power of the equipment replaced by 5,437.80 kW and a reduction in emissions of 636.85 tCO_2/year.
Is this project idea replicable in other districts of Europe? Why? Under which conditions?	It would only be replicable in the same context, i.e. localities in the vicinity of a closed mine shaft that would have to be constantly pumped to maintain the safety level.
Economic Indicators/expected impact	An annual turnover of €120,000 is assumed.
Environmental Indicators/expected impact	Reduction of 636.85 tCO_2/year
Societal Indicators/expected impact	The project means a clear improvement in the environmental quality, access to an efficient technology that provides savings to the end customer, which in the case of Public Protective Housing (PPV) means minimizing the risk of energy poverty.
Overall strategies of city/municipality connected with the project	The Council of Mieres has requested financing from the Mining Funds for the expansion of the DH to access Mieres'public buildings for an amount of 2.5 M€.
Describe strategy	See below
Describe key steps of the process (please indicate between 5 to 10 steps)	1. Have a very particular renewable source (geothermal with mine water) 2. Study the viability of the resource in terms of quality and quantity available 3. See the demand around the production centre 4. Establish contacts with customers 5. Make a business plan to estimate the price at which the kWh could be sold and the necessary investment 6. Seek alternative sources of financing (subsidies, soft credits...) 7. Obtain the licenses and authorization of the affected organisms (Town Hall, Confederation, roads, Patrimony...)
How are citizens involved in decision making process?	In this case, as the action is almost entirely restricted to publicly-owned buildings, no awareness-raising campaign has

	been necessary; the only private building has been incorporated through the approval of the owners' meeting of the offer presented.
Describe financing aspects	Investment of 1,421,541€ (Subsidy of 503,000€) Annual turnover of 120,000€
Describe business model	It consists of a supply contract establishing guaranteed saving respect to the expense used to cover the same demand of conventional fuel (gas) that is covered with geothermal energy.
Regulatory aspects that help the project	All those who favour the energy transition towards renewable energies help this type of action.
Regulatory aspects that hinder the project	Granting of resource exploitation permits, municipal licenses, approvals from the various agencies, make the time for the completion of the project much longer.
Success factors	It is essential that public institutions have an exemplary role in this type of actions, first facilitating contracts' negotiation and then giving confidence to private institutions to join the network.
Challenges and barriers	The main challenge is technological: The transport of the thermal energy to great distances is difficult since the centres of consumption are distant from the centres of production and only in very particular cases the mining wells are in an urban environment. Another thing is that urban operations (technology centres, industrial estates, etc.) can be carried out around wells to minimise the Consumption/distance ratio, which is key in this type of action.

Alessandria, Italy

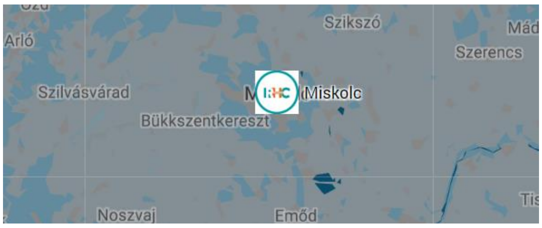


City	Alessandria, Italy
District name	whole town (approx 100,000 population)
Project name	Alessandria high efficiency District Heating
Project status	under construction
Project start – end	2015-2020
Contact	Maurizio.repetto@polito.it
Project website	www.egea.it
Size of project area	6.5 Mm3 heating volume, 800 apartment buildings
Building structure	Existing neighbourhood
Land use (% or m^2/hectare)	4,400 m2 divided in two plants
The DH is located in the city of Alessandria in North-West Italy. The existing built environment is made prevalently by apartment blocks aging from years 60-70 of 1900. Buildings are presently equipped with high temperature central heating systems running on gas or oil fired boilers. In the project, thermal power is provided by a mix of classical, cogeneration gas fired ICEs and backup boilers, and renewable heat coming from solar thermal field and ground source heat pumps connected to the local aquifer. A 60 km piping extension covers the whole city while flexibility of operations is increased by a thermal storage of 2000 m3. As heat must be supplied to end-users at high temperature, a local low temperature grid is created where contributes from solar field and last cooling stage of CHPs are collected. This heat is upgraded at the high temperature value by heat pumps.	
Goals and ambition (it must be about full decarbonisation of a district area)	The project aims at increasing the share of renewable and cogenerated heat and reducing the local pollution by cleaner plants. Two levels of temperature are created to exploit heating in optimal way by different sources. The project has been validated by a dynamic optimization procedure integrated with the design.

Is this project idea replicable in other districts of Europe? Why? Under which conditions?	The project is well matched with all traditional DHs running at high temperature where modifications to the existing building stock are impossible.
Economic Indicators/expected impact	Reduction of operating costs of 3% wrt. Classical DH configuration
Environmental Indicators/expected impact	The main environmental aspects are related to local and global pollution. In details, greenhouse gas reduction (CO2) of 25,2 % with respect to classical cogeneration DH plant. Local pollution reduction 55,5% NOx 33% CO. The target share of cogenerated/renewable energy greater than 60%.
Societal Indicators/expected impact	Increased air quality and reduction of global and local emissions.
Overall strategies of city/municipality connected with the project	Reduction of greenhouse emissions and increase of air quality.
Describe strategy	Integration of different heating sources by means of two temperature levels interfaced by heat pumps. Each heat source provides power at its best temperature reducing losses and increasing system efficiency. Tuning of operations reduces the use of boilers in winter season and completely eliminates their contribute in other seasons.
Describe key steps of the process (please indicate between 5 to 10 steps)	1. Definition of heat demand and its variation through the years reaching a steady state value by 2024; 2. Definition of connections of different components: cogenerators, boilers, aquifer heat pumps, interface heat pumps, solar thermal collectors and storage 3. Simulation of the system by a mixed integer linear programming procedure taking into account three energy carriers: low temperature heat, high temperature heat and electricity; 4. Definition of management strategies as function of load and price variations; 5. Definition of executive design; 6. Deployment and building (under way).
How are citizens involved in decision making process?	Municipality involved in decision-making process.
Describe financing aspects	Project financing
Describe business model	DH classical business model
Regulatory aspects that help the project	N/A

Regulatory aspects that hinder the project	N/A
Success factors	Integration of different heating sources, optimization of management strategies.
Challenges and barriers	Challenges are mainly related to the operative coordination and tuning of the actual plant and its adherence to the nominal working conditions assumed in the Preliminary design phase. Even if the environmental indicators are positive and moving toward a lower carbon footprint of the plant, communication of the whole operation and social acceptance by end-users are issues to be continuously monitored.

Miskolc (Avas), Hungary

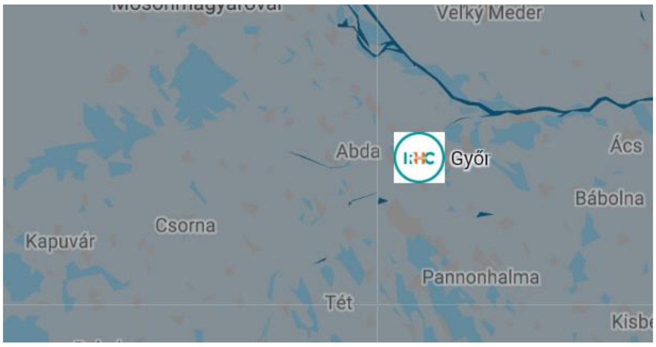


City	Miskolc, Hungary
District name	Avas District Heating System, Miskolc South
Project name	Miskolc Geothermal District Heating Project, Hungary
Project status	Realized, operating
Project start – end	2009 – 2014
Contact	pannergy@pannergy.com; akujbus@geoex.hu
Project website	http://pannergy.com/en/projects/#miskolc
Size of project area	appr. 5 hectares
Building structure	Newly built
Land use (% or m²/hectare)	appr. 5 hectares
Pannergy Plc. with Miskolc Municipality implemented the largest Hungarian geothermal district heating project. The technical goal of the investment was to feed geothermal energy to the heating system of Miskolc's Avas district situated the nearest to the facilities in order to supply heat to the prefabricated buildings of the local housing estates. Two producing wells provide the thermal water. The heat output of the thermal wells are transmitted to the heat consumers via pipelines and heat exchangers, while after cooling down the fluid is reinjected by three reinjection wells. The technology ensures the operations of the largest geothermal heating plant of Central Europe. The Geothermal Project of Miskolc has been recognized with GeoPower Market's international prize "Best Heating Project 2013".	
Goals and ambition (it must be about full decarbonisation of a district area)	Municipality of Miskolc City and PannErgy Plc. decided to decrease the natural gas consumption and hazardous material emission of the city's central heating plant with renewable energy, which would ultimately ensure a cleaner and more livable city for the inhabitants of Miskolc.
Is this project idea replicable in other districts of Europe? Why? Under which conditions?	Yes. Appropriate geothermal potential and enough large heat consumption capacity is needed near each other (< 10 km).
Economic Indicators/expected impact	PannErgy Group received non-repayable grants in a combined amount of more than HUF 1.7 billion from the European Union's European Regional Development Fund and grant schemes funded from Hungary's central budget.

Environmental Indicators/expected impact	• Redeemed natural gas – 55 MW heat capacity • Reduction of CO2 emission – 800–950 TJ/year
Societal Indicators/expected impact	A new renewable energy operating company with dozens of employees : Miskolc Geothermal Ltd.
Overall strategies of city/municipality connected with the project	• The city is supplied with natural gas by the national gas system. Formerly natural gas was the key energy resource for the district heating systems. • Municipality started to implement a “greening” process. • The main energy resources in the city are geothermal energy, biomass and solar energy. • Geothermal energy is appropriate to substitute the largest possible part of the natural gas in the district heating systems.
Describe strategy	The Municipality and PannErgy jointly decided to found a project company, Miskolc Geothermal Ltd. with the intention to supply a large proportion of heat to one of Hungary’s largest cities from renewable resources.
Describe key steps of the process (please indicate between 5 to 10 steps)	• Create energy strategy in the district • Create geothermal strategy (review geothermal potential, prepare technical solutions, implementation roadmap, calculate the economics) • Create financial concept (costs, external supports, heat pricing) • Collecting all permissions • Technical implementation (drilling wells, constructing pipelines, heating centers and accession to the existing district heating system) • Operation and implementation the second phase
How are citizens involved in decision making process?	As the municipality was involved in the Project, the citizens were continuously informed by all possible information resources in the town and also in the region.
Describe financing aspects	• EU based and also Governmental financial supports were important. • Heating price covers the operating costs and ensures the profitability
Describe business model	• Implementation costs were decreased by EU and Governmental financial supports. Supports helped to make the Project profitable.

	• Project costs are returning by the regular income from the heating system.
Regulatory aspects that help the project	receiving permission is easier according to the latest changes of national regulations
Regulatory aspects that hinder the project	maximized heating price
Success factors	• heating capacity • provided annual heat energy • heating factor
Challenges and barriers	The operating system has numerous opportunities: • The system was implemented in two main phases. There is opportunity for further enlargement as well • In upper temperature range (>90oC) electricity generation is to be examined as well • Hybrid energy supplying solutions (with solar and biomass energy resources) are also to be analyzed The barrier is the heat capacity of the reservoir and the thermal water temperature on the head of the wells.

Győr, Hungary



City	Győr, Hungary
District name	Győr District Heating Sytem and Industrial Park
Project name	Győr Geothermal District Heating Project, Hungary
Project status	Realized, operating
Project start – end	2013 – 2015
Contact	pannergy@pannergy.com; akujbus@geoex.hu
Project website	http://pannergy.com/en/projects/#gyor
Size of project area	appr. 5 hectares
Building structure	Newly built
Land use (% or m²/hectare)	appr. 5 hectares

Pannergy Plc. with Győr Municipality and also with Audi Hungaria Motor Ltd. implemented a large Hungarian geothermal district heating project. The technical goal of the investment was to feed geothermal energy to the heating system of Győr district situated the nearest to the facilities in order to supply heat to the prefabricated buildings of the local housing estates. The technology provide heat to the industrial district of Győr as well. Three producing wells provide the thermal water.

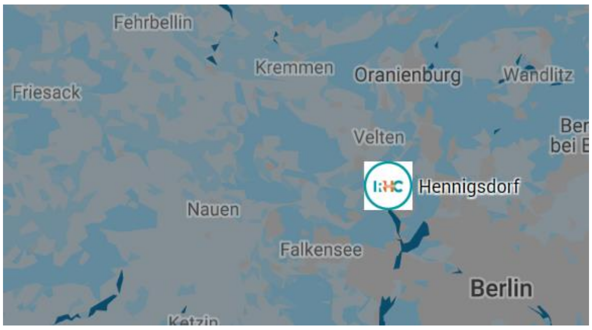
The heat output of the thermal wells are transmitted to the heat consumers via pipelines and heat exchangers, while after cooling down the fluid is reinjected by three reinjection wells. The technology ensures the operations of a large geothermal heating plant and also the industrial district of Győr.

Goals and ambition (it must be about full decarbonisation of a district area)	Municipality of Győr City, Audi Hungaria Motor Ltd. and daughter companies of PannErgy Plc. decided to decrease the natural gas consumption and hazardous material emission of the city's central heating plant with renewable energy, which would ultimately ensure a cleaner and more livable city for the inhabitants of Győr.

Is this project idea replicable in other districts of Europe? Why? Under which conditions?	Yes. Appropriate geothermal potential and enough large heat consumption capacity is needed near each other (< 10 km).
Economic Indicators/expected impact	PannErgy Group received non-repayable grants in a combined amount of more than HUF 2 billion from the European Union based Environmental and Energy Efficiency Operative Programme
Environmental Indicators/expected impact	• Redeemed natural gas – 52 MW heat capacity • Reduction of CO2 emission – 800–900 TJ/year
Societal Indicators/expected impact	A new renewable energy operating company with dozens of employees: Arrabona Geothermal Ltd.
Overall strategies of city/municipality connected with the project	• The city and industrial consumers are supplied with natural gas by the national gas system. Formerly natural gas was the key energy resource for the district heating systems. • Municipality started to implement a “greening” process. • The main energy resources in the city are geothermal energy and solar energy. • Geothermal energy is appropriate to substitute the largest possible part of the natural gas in the district heating systems.
Describe strategy	The Municipality and PannErgy jointly decided to found a project company, Arrabona Geothermal Ltd. with the intention to supply a large proportion of heat to Győr town and also to industrial consumers from renewable resources.
Describe key steps of the process (please indicate between 5 to 10 steps)	• Create energy strategy in the district (both district heating and industry) • Create geothermal strategy (review geothermal potential, prepare technical solutions, implementation roadmap, calculate the economics) • Create financial concept (costs, external supports, heat pricing) • Collecting all permissions • Technical implementation (drilling wells, constructing pipelines, heating centers and accession to the existing district heating system) • Set into operation

How are citizens involved in decision making process?	As the municipality was involved in the Project, the citizens were continuously informed by all possible information resources in the town and also in the region.
Describe financing aspects	• EU based national financial supports were important. • Heating price covers the operating costs and ensures the profitability
Describe business model	• Implementation costs were decreased by EU based national financial supports. Supports helped to make the Project profitable. • Project costs are returning by the regular income from the heating system.
Regulatory aspects that help the project	receiving permission is easier according to the latest changes of national regulations
Regulatory aspects that hinder the project	maximized heating price
Success factors	• heating capacity • provided annual heat energy • heating factor
Challenges and barriers	The operating system has numerous opportunities: • There is opportunity for enlargement of the system • In upper temperature range (>90oC) electricity generation is to be examined as well • Hybrid energy supplying solutions (with solar and biomass energy resources) are to be analyzed • Underground heat storage opportunity is also to be analyzed The barrier is the heat capacity of the reservoir and the thermal water temperature on the head of the wells.

Hennigsdorf, Germany



City	Hennigsdorf in Germany
District name	Entire city of Hennigsdorf
Project name	Heat Hub Hennigsdorf
Project status	under construction
Project start – end	2017 – 2022
Contact	Stadtwerke Hennigsdorf GmbH
Project website	https://www.swh-online.de/aktuell/forschungsprojekte
Size of project area	800 hectares
Building structure	Existing neighbourhood
Land use (% or m²/hectare)	0.5 %
The municipal utility company of Hennigsdorf aims at a district heating with 100 % renewable and CO2-neutral heat in 2025. Until the year 2022 the share of CO2-neutral heat in the district heating with a yearly heat demand of 120 GWh/a will be increased from 50 to 80 % within a lighthouse project. To reach this target, waste heat from the local steelworks, large solar thermal collector fields as well as power-to-heat from renewable surplus electricity production of wind turbines are on the way to be integrated into the district heating net. Biomass driven combined heat and power plants are already used to about 50 % of the annual heat load. To be able to operate the district heating with fluctuating waste and solar thermal heat, the entire network has to be developed to a heat hub by integration of two heat storages of 1000 and 22000 m³. In addition, the reduction of the flow and return temperatures in the district heating network is supported by efficiency measures on the consumer side of the existing buildings.	
Goals and ambition (it must be about full decarbonisation of a district area)	CO2 neutral district heating network for an entire city with 9.800 dwellings (share of about 80 %) and 100 buildings for commerce and industry with a heat demand of 120 GWh/year
Is this project idea replicable in other districts of Europe? Why? Under which conditions?	The district heating of Hennigsdorf is a typical existing district heating network of a mid-sized-town with 26000 inhabitants. One of the main focus points of the lighthouse project is to

	enable the integration of different renewable and CO2-neutral energy sources in an existing district heating network under economic conditions. Thus, it is a prototype for a multitude of cities all over Europe.
Economic Indicators/expected impact	The entire project comprises investments of about 15 million Euro within 5 years. The project is funded by the German Federal Ministry for Economic Affairs and Energy due to its lighthouse character for multiple cities with comparable situations.
Environmental Indicators/expected impact	The heat demand of most of the entire city is going to be transformed from coal fired plants to a heat hub that integrates waste heat and different renewable energy sources with a reduction of CO2-emissions to zero.
Societal Indicators/expected impact	The customers of the district heating network comprise all social classes due to the fact that the district heating network is connected to most of the buildings in the city. All inhabitants of the city of Hennigsdorf benefit in the same way and to the same extend of the project: their heat demand will be delivered CO2-neutral in 2025 with a first step to reach a renewable part of over 80 % per year in 2022.
Overall strategies of city/municipality connected with the project	Since 2006 the overall strategy of the city of Hennigsdorf and the utility is to reinvest in CO2-neutral heat production technologies. In 2015 a climate protection strategy was decided by the municipal council, which is geared to the climate protection plan 2050 of the German Federal Government aiming at a greenhouse gas neutrality of all sectors.
Describe strategy	To legally separate the district heating network and the heat generation, a new project company was founded and the utility began to sell its heating plants to this company. In a first step in 2009 and 2012, a woodchip CHP with ORC technology and a biogas CHP were realized by the project company. At the same time, the different parts of the district heating network were linked and combined to one network. About half of the overall heat demand is provided by these two plants with CO2-neutral heat. Until 2022 the share of CO2-neutral heat is to be increased to more than 80 % as an intermediate step. The completion of 100 % of CO2-neutrality will be reached in 2025.

Describe key steps of the process (please indicate between 5 to 10 steps)	• Use of waste heat from the local steelworks (2019) • Increase of solar thermal heat production (central and decentral) • Use of power-to-heat from renewable surplus electricity • Optimisation of the efficiency of the district heating network and the consumer substations • Dismantling of all old heating plants still burning coal and oil • Realisation of a multifunctional heat storage with 22000 m³ and a buffer tank with 1000 m³ water volume • Development of a smart system control for the entire heat hub
How are citizens involved in decision making process?	The entire project is based on a climate protection strategy that was developed together with the citizens. The Heat Hub Hennigsdorf is based on decisions of the municipal council. All citizens participate at the project by the connection of their dwelling to the district heating net.
Describe financing aspects	To be able to finance this big project, different subsidy schemes were combined in a suitable way: funding of innovative technologies and realisations by the German Federal Ministry for Economic Affairs and Energy with 3.8 mio. Euro and credits from the Reconstruction Loan Corporation.
Describe business model	The utility aims at selling CO2-neutral heat with stable prices in future.
Regulatory aspects that help the project	The project Heat Hub Hennigsdorf put in practise the formal decision of the municipal council of Hennigsdorf for an environmental friendly town. The project is attached to other ones that regard a CO2-neutral electricity production by wind mills in the region around the city.
Regulatory aspects that hinder the project	Although a bunch of innovations is in the Heat Hub Hennigsdorf, most regulatory barriers are raised by the state-of-the-art and existing laws like the cost for using surplus renewable electricity of wind mills, the tunneling of a railway, project coordination with a very lot of different companies etc.
Success factors	A well-rehearsed local project team of technical and project consultants is completed by a research institute that has

	comprehensive experience in consulting and realizing innovative systems like the Heat Hub Hennigsdorf. This team is supported by the management board of the utilities and the municipal council that are willing to make strong decisions for a long term system change.
Challenges and barriers	Financing of this big project by a mid-sized utility is a challenge due to risk management of the banks.