Technical Guidance

On local heat planning for municipalities and service providers

Tallinn University of Technology

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Content

Acronyms

BSR – Baltic Sea Region

CHP – Combined Heat and Power

COP – Coefficient of Performance

DH – District Heating

HP – Heat Pump

ORC – Organic Rankine Cycle

PV – Photo Voltaic

PVT – Photo Voltaic Thermal

RES – Renewable Energy Source

TES – Thermal Energy Storage

1 Introduction

This document provides a comprehensive overview of currently available technologies and the latest best practices in local heat production. As the demand for sustainable energy solutions increases, municipalities are seeking innovative and efficient heating options to align with their strategic goals for clean energy.

Key technologies examined in this guide include:

- **Biomass Technologies:** Biomass boilers and cogeneration plants
- **Heat Pumps:** Ground source, sewage-water, water source (lakes, rivers, sea), large-scale, and individual heat pumps
- **Gas Solutions:** Gas boilers and cogeneration plants
- **Organic Rankine Cycle (ORC) Cogeneration Plants**
- **Solar Thermal Technologies**
- **Electric Boilers and Power-to-Heat Solutions**
- **Thermal Energy Storage:** Short-term (small) and long-term (large) thermal energy storage

Practical insights from tandem partners (technical and municipal) will guide the development of technical scenarios tailored to each municipality. This guidance aims to equip decision-makers with:

- An assessment of the advantages and disadvantages of each technology
- Identification of key drivers and barriers
- A decision-making matrix

With these tools, municipalities can select suitable technical options to achieve a cleaner, more efficient, and smarter local heating infrastructure in the Baltic Sea Region (BSR).

The document also includes best practice examples from partner countries, highlighting successful implementations along with their respective pros and cons. Finally, the document concludes with an analysis of these best practices, providing critical insights and recommendations for future implementations.

This document is provided for informational purposes only. It offers general guidance and illustrative examples and does not constitute legal, financial, engineering, or investment advice. The selection and implementation of measures remain the sole responsibility of the municipality and relevant competent authorities, and should be based on local data, site-specific assessments, applicable permitting requirements, and independent professional advice where appropriate.

2 Technical solutions

2.1 Biomass boiler

Biomass heating systems generate heat from biomass. Instead of relying on fossil fuels like natural gas or oil, biomass boilers use renewable carbon-based materials that can be replenished over time. Biomass boilers may be fully automated or semi-automated. In fully automated systems chipped or ground up biomass is fed to the boiler via conveyors at a managed rate. This rate is managed by computer controls to maintain the pressure and temperature within the boiler. Fully automated systems offer a great deal of ease in their operation because they only require the operator of the system to control the computer.

Pros	Cons
Different kinds of residues and waste can be used to produce heat	Reduced carbon sequestration capacity of forests
Provides market for lower value wood	Extracts nutrients from the soil.
Considerable savings because of low investment costs	Combustion creates air pollutants and fine particles air emissions
Reasonably priced fuel	Fouling tendency

Drivers	Barriers
Availability of large quantities of agricultural, forest, urban and industrial residues and waste to produce heat	Large starting investments
Low price of lower quality wood as fuel	Free space is required to store biomass
Maturity of the technology ensures proven performance, low technical risk, and high reliability	Combustion causes air pollutants, like fine particles etc. Flue gas treatment is necessary.

2.2 Biomass cogeneration plant

Biomass cogeneration, also known as a combined heat and power (CHP) system, is a process that produces electricity and heat simultaneously from biomass. Sources of biomass may vary, from wood to green waste and agricultural residues. This environmentally friendly and economical system offers a sustainable solution, effectively helping reduce greenhouse gas emissions. Biomass cogeneration operations are based around a device that includes a combustion chamber, a boiler, an alternator and turbines. The fuel is incinerated, creating heat that transforms water into steam. That steam is used to generate mechanic energy for the turbine which generates electricity. After releasing the heat, steam is condensed and cooled, the cycle starts over again.

Pros	Cons
High overall fuel use efficiency	Low energy density
Dispatchable, controllable renewable energy	Seasonality issues
Local biomass waste valorisation & rural development	Air emissions (fine particles)
Potential GHG benefits	Low efficiency if sufficient heat load is not available

Drivers	Barriers
Need for base load heat and electricity production	High transport and storing costs due to low fuel energy density
Waste reduction	Profitability depends on stable, affordable fuel prices
Creates jobs locally	Sufficient heat demand is necessary
Rural development	

2.3 Heat pumps

2.3.1 Ground source

Shallow ground-source heat pumps (GSHPs) use renewable energy stored in the ground. Heat pump is counted to large-scale category if it has a capacity of at least 1000 kW. The range of heat pumps is large depending on the technology employed; with centrifugal compressor type, the range could go up to as much as 30 MW. Typical heat pump (HP) supply is 65–90 °C, up to 100 °C is possible for dedicated high-temperature HP designs, depending on source temperature and refrigerant. Large heat pumps in DH systems can be very energy efficient, hence excellent in the reduction of energy costs when the difference between the heat source and the heat sink temperature is low. Large-scale heat pumps can enhance low-grade heat to substantial heat for efficient and reliable application in DH systems. GSHPs use low-temperature heat stored in the ground or large bodies of water as an energy source. Heat is transferred from the ground or water source and delivered to a building in winter months. This can be reversed in summer months, and heat from a building can be stored in the earth to be used at another time.

To compare different HP efficiencies, a parameter – coefficient of performance (COP) is very often used. That describes how much electricity a HP consumes to produce heat. For example, when COP is 3, then a HP uses 1 MW electricity to produce 3 MW heat energy. Normally, COP depends on heat source temperature, the higher the heat source temperature is, the higher COP can be achieved. Average COP for ground source HP is 3.5-5. The cost per 1 MW installation is about 2.2-3.6 Meur.

Pros	Cons
Little if any serious environmental risks	Thermal imbalance after long-term operation
GSHPs use less energy than alternative heating and cooling systems	Changes to water and soil microbiomes
GSHPs can be scaled economically	Sulphate oxidizing bacteria at ranges of temperatures
Proven long-term performance (in many contexts)	Serious risks drilling and installation damage

Drivers	Barriers
Available land for installation	High initial costs
Good thermal gradient and capacity	Environmental risks from drilling
Policy and incentives, decarbonisation targets	Long-term ground performance uncertainty
	Skills, supply-chain maturity and low public awareness

2.3.2 Sewage-water heat pump

A large-scale sewage wastewater heat pump is a high-capacity heating system (usually 0.5 - 20 MW_{th}) designed to recover and upgrade thermal energy from municipal wastewater for use in district heating networks, industrial processes, or large public buildings. The technology integrates wastewater infrastructure with heat pump thermodynamics to extract low-grade heat (usually 10–25 °C) and raise it to supply levels between 55 °C and 90 °C, suitable for district or process heating. The heat pump extracts heat (heating mode) or rejects heat (cooling mode) usually via a heat exchanger, possibly with pre-treatment or using special exchangers to deal with fouling etc. COP is around 4-6, Cost per 1 MW installation is around 0.7 – 1.6 Meur.

Pros	Cons
High and stable heat source temperature	Large dependency of sewage quality
High COP due to high heat source temperature	Heat exchanger fouling and retrofitting
Versatility – heat pumps can be used for heating and cooling	System needs to be cleaned and inspected regularly
Suitable for urban environment	

Drivers	Barriers
Flexibility and sector-coupling potential	High installation costs
Sewage water treatment near urban settlement	Restrictions due to waste-water treatment process
High sewage wastewater temperature (higher than ambient temperature)	Regulatory and institutional challenges

2.3.3 Water source (lakes, rivers, sea, etc) heat pumps

A water source heat pump uses the heat energy from water to provide heating and hot water. There are two main water source heat pump designs: open loop systems and closed loop systems.

Open loop systems: Open loop systems directly draw water from artificial or natural water source such as lakes, rivers, aquifers to extract heat (heating mode) or reject heat (cooling mode). After passing through the heat pumps heat exchangers, it is immediately returned to the source or discharged downstream. Main advantages are the lower installation costs, stable temperatures if large water bodies are used or groundwater and high heat transfer efficiency because of the direct contact with the water source.

The main difference between an open loop and closed loop system is that in a closed loop system a sealed piping circuit is filled with water or water and glycol mixture. The mixture goes through a heat exchanger that is submerged in or near the water body and there is no contact between the heat pump fluid and the water body. Water source heat pumps have an average COP of 3,5-6. Cost per 0.25 – 0.33 Meur/MW

Pros	Cons
High and stable source temperature	Fouling, biofouling and corrosion
Large, scalable resource for district heating and cooling	Environmental impact to aquatic ecosystems
"Free cooling" during summer period	Dependence on flow rate, seasonal and local variability
Long lifetime and predictable operation	Higher material and equipment cost
	Permitting complexity

Drivers	Barriers
Decarbonisation and policy push	High upfront costs and infrastructure upgrades
Mature technology	Policy and market barriers
Flexibility and sector-coupling potential	Electricity market exposure
	Operational risks

2.3.4 Other type of large scale heat pumps

Large Heat Pumps (LHP) are utility-scale heating plants that allow to transfer large quantities of heat from a colder source, like environmental heat or industrial waste heat, to a higher temperature heat user, like a district heating network or an industrial process. Cost per 1 MW installation is around 0.32-0.5 Meur.

Pros	Cons
Big carbon and fossil-fuel reductions	High upfront capital costs
Recovery and upgrading of low-grade waste heat	Need for network and infrastructure upgrades
System flexibility and renewables integration	Heat source or -sink constraints
Favourable levelized costs in many contexts	Technical limits at high temperatures
	Refrigerant issues
	Market, regulatory and financing barriers

Drivers	Barriers
Possibility to couple with other energy sectors	High upfront costs
Unit costs per kW can decline	Market and regulatory barriers
	Technical challenges

2.3.5 Individual heat pumps

In case of individual heat pumps, there are two main types of heat pumps mostly used: Air source and ground source.

Air source heat pump draws heat from the outside air during the heating season and rejects heat outside during the summer cooling season. Even in colder weather a lot of energy is still available that can be extracted. Air source heat pumps go into two separate categories: Ductless and ducted.

Air-air systems, which use air as heat source (take heat from ambient air) and use air also as heat carrier (heat is provided as warm air blown to the room), are more efficient when the temperature difference between inside and outside is smaller. Because of this, air-air heat pumps generally try to optimize their efficiency by providing a higher volume of warm air, and heating that air to a lower temperature.

There are also air-water HPs, which also use ambient air as heat source, but use water as heat carrier in the heating system. These types of HPs heat or cool water and are used in homes with hydronic (water-based) distribution systems such as low temperature radiators, radiant floors, or fan coil units. In heating mode, the heat pump provides thermal energy to the hydronic system. This process is reversed in cooling mode, and thermal energy is extracted from the hydronic system and rejected to the outdoor air.

Ground source HPs use the earth or ground water as a source of thermal energy in heating mode, and as a sink to reject energy when in cooling mode. These types of systems contain two key components:

1. Ground Heat Exchanger: This is the heat exchanger used to add or remove thermal energy from the earth or ground. Various heat exchanger configurations are possible.
2. Heat pump: Instead of air, ground-source heat pumps use a fluid flowing through the ground heat exchanger as their source (in heating) or sink (in cooling). Heat pumps operate more efficiently when heating at lower temperatures of below 45 to 50°C, making them a better match for radiant floors or fan coil systems. Ground-source systems are able to operate more efficiently because they take advantage of warmer and more stable ground temperatures. Typical water temperatures entering the ground-source heat pump are generally above 0°C, yielding a COP of around 3 for most systems during the coldest winter months. Air-water cost 1-1.5 Meur/MW and ground source cost is around 2-4 Meur/MW.

Pros	Cons
High operational efficiency compared to combustion heating	High upfront cost for ground-source systems
Year-round heating and cooling	Installation complexity for ground-source systems
Low operating costs in mild climate	Performance drop in very cold climates
Enables electrification and integration with renewables	Mismatch with existing low-temperature distribution
Flexibility (can produce heating, cooling and domestic hot water)	Retrofitting needs
Mature technology	High maintenance costs
	Refrigerant risks and embodied emissions

Drivers	Barriers
Favourable policy	High installation costs
Funding support	Confidence and perceived risk
Excess of renewable electricity	Mismatch with buildings and heating system
Easy to use and install	Lack of information, awareness
	Electricity cost and price structure

2.4 Gas boilers

A gas boiler is a widely used technology for producing heat in district heating systems or individual heating applications. It operates by burning natural gas (or biogas) in a combustion chamber to heat water, which is then distributed through a heating network. Gas boilers are nowadays mainly used for covering peak load, as they start up fast and can change load rapidly. They are very often combined with biomass boilers, where base load is covered by biomass and peak loads and low demand periods (summer, when only domestic hot water is needed) are covered by gas boilers. The base load can also be covered by heat pumps. In such systems, the heat pump provides efficient heating when outdoor temperatures are mild, while the gas boiler supports or takes over during colder periods when the heat pump's efficiency drops. This combination improves overall energy efficiency, reduces heating costs, ensures reliable operation in all weather conditions, and can lower carbon emissions compared to using a gas boiler alone.

In most cases gas boilers use natural gas, which is fossil fuel. Although natural gas is imported fuel for most cases in Baltic Sea Region, is highly available. The fuel price can be volatile, which can cause unpleasant surprises for both consumers and producers. As for most imported fuels, the question of availability and dependence remains. These are the main reasons for transition from natural gas to other heat sources is important.

Natural gas can also be replaced with biogas or other renewable gas products, which are also available nowadays. Main biogas sources are organic waste materials processed through anaerobic digestion, primarily including animal manure (cattle, pigs, poultry), agricultural residues (straw, sugar beet), energy crops (silage corn), and municipal/industrial organic waste (sewage sludge, food waste). This makes biogas local fuel and this means that the risks that are before mentioned for natural gas are not relevant for biogas. Still, the availability of biogas is not yet as good as for natural gas, in most BSR countries, the gas networks still contain mostly natural gas, rather than biogas.

Pros	Cons
Proven technology	Price volatility
Flexible operation	Emissions (CO_2, NO_x, CH_4)
High efficiency	Not renewable (if natural gas is used)
Low fine particle emissions	
Reliable backup	

Drivers	Barriers
Decarbonization via biogas or synthetic methane	Regulations (emission, carbon taxes – if natural gas is used)
Hybrid system with heat pumps	Infrastructure dependence (gas network)
Peak load and low demand covering	

2.5 Gas cogeneration plant

A gas cogeneration plant, electricity and useful thermal energy are simultaneously produced from from natural gas or biogas. In this process, a gas engine or turbine drives a generator to produce electricity, while the waste heat from exhaust gases and cooling systems is recovered and used for heating, hot water, or industrial processes. This combined use of energy allows overall efficiencies of up to 80–90%, significantly higher than conventional power generation. Due to their high efficiency gas cogeneration plants use less gas to produce the same energy output compared to natural gas combined-cycle power plants offering a reliable solution for handling varying demand.

Pros	Cons
High efficiency	Large CO_2 footprint (if natural gas is used)
Widespread technology	Volatile fuel prices
Fast start-up	Need for extensive infrastructure
Options for alternative fuel (biogas)	
Higher efficiency compared to stand-alone plants	

Drivers	Barriers
Subsidies for CHP plants	High initial investment
	Efficiency drops when heat or power demand varies
	Competition with environmentally friendly alternatives

2.6 ORC cogeneration plant

An Organic Rankine Cycle (ORC) cogeneration plant is a system that simultaneously produces electricity and useful heat from a single fuel source—typically low- to medium-temperature heat streams that conventional steam turbines cannot efficiently use. ORC systems are widely applied in biomass plants, geothermal installations, industrial waste-heat recovery, and small-scale distributed energy systems.

An ORC cogeneration plant uses an Organic Rankine Cycle, which is similar to the conventional steam Rankine cycle but uses an organic working fluid (such as pentane, toluene, or refrigerants) instead of water.

Organic fluids have lower boiling points and higher vapor densities, allowing efficient energy conversion from heat sources ranging from 70°C to 350°C, which are too low for steam turbines.

Pros	Cons
Small CO_2 footprint (if RES is used as fuel)	Low efficiency
Many sources of waste heat can be used	Expensive organic fluids
Solutions are scalable	Toxic and flammable organic fluids

Drivers	Barriers
Carbon neutral (if RES is used as fuel)	High initial investment
Need for base load heat and electricity production	Regulatory restrictions
	Limited production capacity

2.7 Solar thermal

Solar thermal district heating (DH) systems use ground-mounted solar collectors (usually flat-plate panels) to convert sunlight into heat. Sunlight is absorbed by a metal absorber plate behind a glass cover, heating a circulating fluid (water or water–glycol). That hot fluid then passes through a heat exchanger to warm the district heating water. Because solar heat is intermittent, solar fields are used alongside conventional boilers or heat pumps; thermal storage (short-term tanks or long-term seasonal stores) is typically included so that summer solar heat can be shifted to meet colder season demand. Properly designed panels work even in cold weather (with antifreeze fluid) and have protection against overheating.

A solar DH plant typically includes the following parts:

- Collectors: Flat-plate solar panels (metal absorber, glass cover, insulation) that capture solar energy.
- Fluid piping: Tubes connecting the panels, circulating the heat-transfer fluid.
- Storage tank(s): Insulated tank(s) for short-term or seasonal heat storage.
- Heat-transfer fluid reservoir: Tanks or vessels holding the water/glycol mixture.
- Heat exchanger & pumps: Equipment and valves to transfer heat from the solar loop to the district heating circuit.

The input is solar radiation (direct and diffuse sunlight). Collectors convert roughly 40% of incident sunlight into useful heat (depends on the conditions). The output is hot water delivered into the district heating network. Annual heat yields are roughly 300–600 kWh per square meter, depending on climate and system design. In practice, ~450 $kWh/m^2 \cdot yr$ is a typical long-term average in Danish solar fields. Because production drops at higher panel temperatures (and in low sun), yield is highest when heating needs are lowest (summer). This means that solar thermal installations go together well with thermal storages, so the use for harvested heating energy can be maximised.

Pros	Cons
Cost-efficient renewable heat	Intermittent production (time of day, clouds)
Low operational complexity and cost	High upfront capital cost
Zero on-site emissions	

Drivers	Barriers
Municipal sustainability goals	Environmental permitting (land use)
Carbon pricing	Technological complexity of the system
High electricity prices	
Possibility to produce heat to storage	

2.8 Electric boilers (power-to-heat)

Power-to-heat describes a process in which electrical energy is converted into thermal energy, usually carried out with electric- or electrode boilers, which produce heat when electricity is generated at lowest market prices. These kind of systems go together well with thermal energy storages.

An electric boiler's key components include an insulated pressure vessel and the heating elements or electrodes inside it. In smaller boilers these are simple metal-resistance heating rods; in larger boilers (electrode boilers) a set of three-phase and neutral electrode rods are inserted into the water chamber. The vessel is usually pressurized with an inert gas (e.g. nitrogen) to prevent boiling and to raise the boiling point of water. Components include circulation pumps, valves, and control systems. Unlike combustion boilers, there are no fuel lines, burners or flues. All power is supplied by high-voltage electrical connections directly to the heater elements, and a control system regulates the current (hence heat output) by adjusting flow or electrode contact. Because there is no combustion, boiler internals experience far lower thermal stress and require much simpler maintenance. Power-to-heat technologies, including electric boilers are essentially 100% efficient in converting electrical energy to thermal energy.

Pros	Cons
Near-100% conversion efficiency	High quality energy is turned into low quality energy
Few moving parts	High dependence on electricity prices
Zero on-site greenhouse gas emissions	Risk of indirectly increasing greenhouse gas emissions if electricity comes from fossil fuels

Drivers	Barriers
Rising carbon prices	Grid capacity limitations
Use of surplus electricity from RES	Potential upgrades needed e.g combining with wind turbines for peak hours
Power grid balancing	

2.9 Thermal energy storages

Thermal energy storage (TES) systems can store heat or cold to be used later, at different conditions such as temperature, place, or power. TES devices consist of a heat carrier – a storage medium that can store heat that is available over a certain period for later use (without phase change).

2.9.1 Small (short-term) thermal energy storage

With the help of a heat storage system, it is possible to cover 20–25% of the heat energy demand from surplus renewable energy. Accumulation tanks are mainly used as short-term heat storage. In case of biomass boilers, short-term storages smooths out generation peaks, thus improving heat generation efficiency. There are two types of short-term accumulator tanks: high-pressure and atmospheric pressure.

Pros	Cons
Energy efficient technology	High initial costs
Cost savings	Space requirements
Flexibility	Material limitations
Renewable integration	High Initial Investment
Reduced emissions	
Fit for the industries	

Drivers	Barriers
Potential cost savings	Low economic feasibility
Emissions reduction	Storage efficiency
Possibility to couple with RES like solar thermal collectors	Technical complexity
Integration of renewables	Site constraints

2.9.2 Large (long-term) thermal energy storage

Seasonal or long-term storage is generally used to store solar energy or residual summer heat from power plants for use during the winter period. Thus, the number of charge and discharge cycles during the year is low and the amount of energy stored is small. Therefore, seasonal storage is as simple as possible: large-scale and non-pressurized systems (tank, pit, borehole, aquifer thermal energy storage). Tank thermal energy storage as the most efficient one is generally made of concrete, steel or reinforced plastic (layer elements). Concrete tanks are built from in-situ concrete or prefabricated concrete elements. An additional lining (polymer, stainless steel) is usually attached to the tank surface to prevent water vapor diffusion and to seal the structure. Insulation is placed on the outer surface of the tank. Typically, this type of storage tank has high heat losses. In general, large-scale steel tanks (both insulated and uninsulated) located above ground are state of the art.

Pros	Cons
High heat capacity	Limited size (<100,000m³)
Repair options	Higher primary energy requirements compared to other storage tanks
Good performance parameters (high loading and unloading capacity)	High installation costs
Few designs restrictions	High self-discharge rate
Thermal stratification	
Low maintenance costs	

Drivers	Barriers
Potential cost savings	Low economic feasibility
Emissions reduction	Storage efficiency
Possibility to couple with RES like solar thermal collectors	Technical complexity
	Site constraints

3 Decision-making matrix

The decision-making matrix considers two parameters, annual heat consumption and heat consumption density, to decide whether a technology is feasible and its using is environmentally justified.

Annual heat consumption refers to the total amount of heat delivered by the network over a year. This metric is vital for assessing the capacity requirements of the district heating system, ensuring that the energy production facilities are appropriately sized to meet the demand. Accurate estimation of annual consumption enables operators to optimize resource allocation, reduce energy waste, and enhance overall system efficiency. It also aids in financial forecasting and investment decisions, helping to ensure the long-term viability of the network.

Heat consumption density, on the other hand, reflects the concentration of heating demand within a given area. For DH network, it is easier and more reasonable to measure the heat density in MWh per meters of pipelines, as the heat consumption and network length are well known parameters for DH companies and utility providers. Heat consumption density is essential for understanding the economic feasibility and operational efficiency of district heating systems. High consumption density typically leads to reduced infrastructure costs, as it allows for shorter and fewer distribution pipelines, minimizing heat loss during transit. Furthermore, areas with higher heat density can support more sustainable energy solutions, such as integrated renewable energy sources and combined heat and power (CHP) systems, thus contributing to reduced greenhouse gas emissions.

Together, annual heat consumption and heat consumption density provide critical insights into the design, operation, and sustainability of district heating networks. By evaluating these parameters, planners and operators can enhance energy efficiency, optimize investments, and create resilient heating solutions that support sustainable urban development. As cities continue to grow and face the challenges of climate change and energy security, a thorough understanding of these metrics will be increasingly important in shaping the future of district heating.

3.1 Annual heating consumption

Micro (less than 1500 MWh)

These kinds of settlements are small and mostly rural. They consist of few apartment buildings, normally less than 10 multi-family houses and some municipal buildings like kindergarten, school and local municipality.

They are common in Baltic rural areas, in Estonia, Latvia and Lithuania.

Small heat consumption is quite often the biggest issue for local district heating network and finding new consumers is crucial for district heating network vitality. For these networks it is very hard to make investments and without governmental support it is impossible to renovate piping, heating production technologies and provide reasonably priced heat for citizens.

In such areas, the future of district heating is often uncertain. When it becomes clear that there is no possibility of increasing heat consumption, residents frequently switch to individual heating. This shift typically marks the end of district heating in the area.

Recommended technologies:

- Biomass boiler – if biomass is available
- Ground source heat pump – subsidies for installation are necessary

Recommended actions:

- Increase heat consumption via new consumers
- Switch to individual heating if not possible to find new consumers

Small (1500…50 000 MWh)

These kinds of settlements are small towns for Baltics and Finland, for Poland, Sweden and Germany this means a very small village. The main consumers in district heating network are multi-family houses, but key consumers are normally still municipal buildings – local school, kindergarten, sports facilities and municipality buildings.

For these networks the viability and future of district heating is not questionable but increase of consumption and new consumers can remarkably increase feasibility of investments and lower heating price for consumers. Subsidies for investments are necessary.

Recommended technologies:

- Biomass boiler – if biomass is available
- Sewage-water heat pump – subsidies for installation are necessary

Recommended actions:

- Increase heat consumption via new consumers
- Keep up with renovations in district heating network to keep network viable

Medium (50 000…200 000 MWh)

For Baltics and Finland this kind of settlement represents medium sized towns, where most of heat consumption comes from residential buildings. Key consumers are also schools, kindergartens, municipality buildings, shops and businesses buildings, sport facilities etc.

The network can be divided into sub-districts and each district can have different heat production technologies. The sub-districts can be connected to each other.

These kinds of towns have more options for choosing heat production technologies, as sufficient amount of heat demand is mostly guaranteed and payback time for investments is reasonable.

If there are industries nearby, then using their waste heat can be a good solution.

Recommended technologies:

- Biomass cogeneration plant
- ORC-combined heat and power plant
- Centralised heat pumps
- Solar thermal
- Industrial waste heat, if available

Recommended actions:

- Keep up with renovations in district heating network
- For transition to lower network temperatures, energy cascade solutions can be suggested. This means that DH networks have sub-districts where lower supply temperatures can be used. These sub-districts get their supply from high-temperature DH network return flow, which is approximately equal to sub-district's supply temperature. This lowers also the return temperature in high-temperature DH network and when these kinds of low-temperature sub-districts grow, the network gradually moves towards lower network temperatures.

Big (200 000 MWh and more)

For Baltics this means a big city, normally a centre of county. For other Baltic Sea Region countries (Finland, Sweden, Poland and Germany) this can be a small town. The recommendations also extend to bigger cities.

These municipalities have more flexibility to decide how to produce heat and installing heat storages and various of renewable energy sources can be feasible.

These networks are normally divided into sub-districts and have several heat production facilities, including different boilerhouses. Sufficient heat demand is not an issue for most time of year and combined heat and power plants can be established.

For these networks, one of the goals would be lowering flow temperature in district heating network, it can help to reduce heat losses and makes different kind of renewable energy sources more available and increases their efficiency – for example low-grade heat that can be used via heat pumps.

In those towns and cities district cooling can also be used. This can also help to increase the efficiency of some technologies that are used for heat production - such as combined heat and power plants and heat pumps.

Majority of the heat consumption in those networks comes from residential buildings, there are also many commercial and business buildings, also schools, kindergartens, sports facilities, municipality buildings etc.

Recommended technologies:

- combined heat and power plant
- waste incineration plant
- centralised heat pumps
- thermal energy storage
- solar thermal
- power-to-heat (if there is CHP and several solar-photovoltaic panels)
- industrial waste heat, if available

Recommended actions:

- for transition to lower network temperatures, form sub-district where lower temperature can be used already and like so gradually achieve low temperature district heating

3.2 Energy consumption density

Sparse energy consumption density (less than 1.5 GWh/km)

In areas with sparse energy consumption density, heat losses are greater and investments needed for pipe renovation are higher. These combined factors have a significant negative effect on the feasibility and viability of the network.

Sparse energy consumption density, specifically when annual heat consumption is low, eventually leads to individual heating suggestion.

To avoid high energy losses in district heating network good piping insulation is crucial.

Normal energy consumption density (1.5…3 GWh/km)

For normal energy consumption density relative heat losses are below 20% and can be lowered with sufficient piping insulation and lower temperatures in district heating network.

High energy consumption density (more than 3 GWh/km)

High energy consumption density enhances the economic and environmental performance of district heating systems, making them more viable and sustainable energy solutions for densely populated areas. In this case individual heating solutions are less recommended.

3.3 The matrix

In this section two matrix in form of a coloured table are presented – one for economic objectives (for cost effectiveness) and the other for environmental objectives (for emissions and other environmental concerns)

3.3.1 Economic objectives

Evaluation of economic objectives is rated in three-star scale. These ratings consider:

- Investments and simple payback period
- Operation and maintenance costs
- Fuel costs (if applicable)

1 – Not recommended

The solution is not economically feasible therefore is not recommended. This can be caused by unreasonably long simple payback time for investments, high operation and maintenance costs or other costs that are accompanied by using that technology.

2 – Moderate

The solution can be used, although there can be either slightly long investments payback period or it might happen that using that technology can have sometimes high accompanying costs.

3 – Recommended

The solution is economically feasible, has short investments payback time and does not have high operational costs.

3.3.2 Environmental objectives

Evaluation of economic objectives is rated in three-star scale. These ratings consider:

- greenhouse gas emissions (CO_2 and other)
- fine particle emissions
- environmental risks of pollution
- other environmental risks

1 – Not recommended

The solution is not suggested, it has either high greenhouse gas emissions, fine particles emissions or it can cause serious risks for environmental pollution or other environmental risks are high.

2 – Moderate

The solution can be used, but there are some environmental issues that should be considered and, in the future, it might not meet the environmental requirements. It might produce either greenhouse gas emissions or it has slight risks for environmental pollution.

3 – Recommended

Using the solution is suggested, it does not have any significant emissions and it does not cause any serious environmental risks for pollution.

3.4 Example of using the matrix

A small city with 27 500 MWh annual heat consumption and 13 km district heating network would like to see which technologies are suggested for heat production.

According to beforementioned limits of the parameters, it is a small town with normal heat consumption density.

The decision-making matrix gives the following result:

RESULTS			
	Economic objective	Environmental objective	COMMENT
biomass boiler	3	2	Biomass is renewable and reasonably priced, fine particle emissions must be taken care of.
biomass CHP	1	2	Heat consumption is too low for installing CHP, fine particle emissions must be taken care of.
large heat pump	1	3	Low heat consumption can extend the invest payback period, if natural heat sources and renewable electricity are available then environmentally good option.
gas boiler	2	1	Fuel price can go up as natural gas is fossil fuel, but installing investments are reasonable. Environmentally not recommended.
gas CHP	1	1	Heat consumption is too low for installing CHP, high GHG emissions.
ORC CHP	1	3	Heat consumption is too low for installing CHP. If natural heat sources are available, then can be considered when heat consumption increases.
solar thermal	3	3	It can be good solution to provide renewable energy to heating network.

electric boiler	2	3	Electricity price can be volatile, but installing investments are reasonable. If renewable electricity is available then it can be good option for backup and peak loads.
Thermal energy storage (small)	1	3	Heat consumption is too low for installing TES, if heat consumption increases and renewable energy is highly available, then would be recommended.
Thermal energy storage (large)	1	2	Heat consumption is too low for installing TES, if heat consumption increases and renewable energy is highly available, then would be recommended.
individual heat pumps	3	3	Individual heat pumps can be recommended if district heating is not viable anymore. Best solution for individual heating.

4 Examples of best practices

This chapter includes best practices from all partner countries of PlanHeat project.

4.1 Best practices from Estonia

4.1.1 Rakvere

GENERAL DATA

Population of the municipality: 14 731 (01.01.2026)

Number of district heating consumers in the municipality: 194 buildings, including:

- local government and state-owned enterprises (32%)
- companies (16%)
- apartment associations (52%)
- private houses

District heating network length: 21.5 km

Annual heat consumption in the district heating network:

- Südalinna area: 38 000 MWh
- Lennuvälja area: 1300 MWh
- Vanalinna area: 600 MWh
- Kuketüla area: 500 MWh
- Total: 40.4 GWh

DESCRIPTION OF USED HEATING TECHNOLOGIES

Rakvere has four district heating areas – Südalinna, Lennuvälja, Vanalinna and Kukeküla – which are not connected by pipelines but operate as a single district heating system with one unified price for all consumers. Rakvere district heating network has been awarded The Efficient District Heating label.

94% of heat is consumed in the largest area – Südalinna. The pipeline extends to 20 km, which accounts for 94% of the total length. A **2 MW wood chip boiler house** was built in 2009 and a few years later (in 2012), a heat purchase competition was organised to increase the share of renewable energy. This resulted in an additional **5.3 MW$_{th}$** cogeneration plant (**CHP**) being built in the Südalinna network area, on **Päikese** street. Both the boiler house and the CHP are owned and operated by Adven. Based on production data, the share of cogeneration is 66%.

Fig. 1. Rakvere Adven CHP (Photo from Adveni Fotokogu)

The other small areas use natural gas for heat production, making Südalinna the only area using renewable energy. One boiler house is located on **Roosi** street and includes two gas boilers - 1.75 MW and 3.2 MW. **Lembitu** street boiler house also includes two gas boilers, 8.5 MW each.

Fig. 2. Lembitu and Roosi boiler houses (Photos from Rakvere city district heating development plan 2016-2026)

Südalinna CHP and boiler house cover the base load in the main network area; natural gas covers peak demand and provides backup if needed. In the summer, the CHP must be shut down due to lower heat demand. The average relative heat loss of the network is 16.8% and around 77% of the pipes are renewed.

ADVANTAGES

Rakvere, being the 8th largest city of Estonia, has made great use of biomass CHP technology – providing renewable electricity and heat to locals, while using less primary energy and increasing efficiency. Päikese street CHP and the additional wood chip boiler provide district heating to a large part of Rakvere, especially to apartment buildings. This helps the network lower emissions and maintain its Efficient District Heating label – ensuring reliable energy for consumers.

The base load is covered by domestic and reliable fuel - wood chips – strengthening energy security, utilising forest waste and providing affordable energy. Natural gas ensures heat production during peak demand and colder winter months in Rakvere.

LESSONS LEARNED

Due to considerably lower heat demand during summer, the cogeneration plant must be shut down for this period of the year.

Recent building renovations in Rakvere (80% of apartment buildings between 2013-2025), has caused the reduction of district heating demand, which in turn has led to higher DH prices. Renovations have either been made with a ventilation air heat pump solution or without it (total installed capacity 1.6 MW).

In renovated buildings with a heat pump solution, DH consumption has decreased 80%, compared to 35% in buildings without heat pumps. Since the heat pumps use non-renewable electricity, CO_2 emissions did increase. Other problems include the increase of heat losses in DH network and parallel energy consumption, which means that a consumer (an apartment building, for example) uses heat from DH network and also uses some individual heat production technologies, like there is installed an ventilation heat recovery heat pump and the consumer uses both these sources in the same time. For DH network this means unexpected drop in consumption which decreases efficiency.

4.2 Best practices from Lithuania

4.2.1 Klaipėda City Municipality

GENERAL DATA

Population of the municipality: 161 205 (record of January 1, 2025)

Fig. 1. AB Klaipedos energija ((Photo by Klaipėda Energy))

Number of district heating consumers in the municipality:

- 57 industrial companies;
- 57 municipal and state budget institutions;
- 1 949 businesses and public institutions;
- 70 000 residential consumers.

District heating network length(optional): approx. 208 km

Annual heat consumption in the district heating network (2024):

- Heat generation by AB "Klaipėdos energija": 279,200 MWh;
- Heat generation by 5 independent heat producers: 522 200 MWh;
- Heat supply to the pipeline: 801 400 MWh;
- Heat losses in the pipeline: 102 500 MWh;
- Heat sales: 694 600 MWh.

DESCRIPTION OF USED HEATING TECHNOLOGIES

District heating company AB Klaipėdos energija is the supplier of heat, hot water and steam (for industry) in the municipality, operating 3 large boiler-houses with 10 water heating boilers and 6 steam boilers, with a total capacity of 648 $MW_{th,}$ as well as 15 small boiler-houses with 28 water heating boilers with a total capacity of 1.9 MW. The main fuel is biomass (wood chips from the Biomass trade "Baltpool") – 85%, and natural gas – 15 %.

Heat is also produced by 5 independent heat producers:

- UAB GREN Klaipeda (**Heat CHP burning Municipal Solid Waste (MSW)**, one of 3 in Lithuania). Installed capacity – 85 MW_{th}, 20 MW_{el}, heat production 441 736 MWh/a (2023);

Fig. 2. UAB GREN Klaipeda (Photo by UAB GREN Klaipėda)

- UAB Pramones energija (heat production 83.525 MWh/a);
- AB Klaipedos mediena (**waste heat from wood processing and furniture industry**, heat production 44 542 MWh/a);
- AB Klaipedos baldai (**waste heat from the furniture industry**, heat production 9 732 MWh/a);
- UAB Miesto energija (heat production 1 279 MWh/a).

Energy efficiency installations:

- A condensing economiser for each biomass boiler, adding approximately. 8 MW of heat for hot water production;
- Absorption heat pumps for the recovery of waste heat after the economiser, adding 1.2 MW of heat.

Other renewables, already used and/or planned:

- 100 kW of **PV panels** + 200 kW are under installation in various boiler-houses of the DH company, and a total of 500 kW is planned to produce heat (hot water), when there is no need to use fuel, natural gas or even biomass.
- **Geothermal energy** - AB Klaipėdos energija signed an agreement with Klaipėda City, which is located in the geothermal anomaly zone of western Lithuania, characterised by high-temperature (35–90 °C) geothermal water deposits at a shallow depth (1–2 km). This represents significant geothermal potential – enormous amounts of energy are stored here, the effective use of which would reduce heating costs for residents while ensuring a lower negative impact on the environment. A demonstration geothermal power plant operating in Klaipėda from 2002 to 2017 proved that geothermal energy can be used in a district heating system in Lithuania. Unfortunately, during its operation, the power plant encountered technical and economic challenges that could not be overcome, and it was shut down. However, these challenges also served as lessons learned, and geothermal energy could be used for DH.

Fig. 3. AB Geoterma (company picture)

Heat Storage - Several years ago, due to the fast development of the use of woody biomass in the district heating sector, the requirement for solutions related to the specifics of biomass installations and the efficiency of such systems raised the importance of heat accumulations in the sector. Container or tank-type water-based storage is the simplest solution and thus the most popular in Lithuania.

Fig. 4. The heat storage in Klaipėda City (Photo by Klaipėda Energy)

On the territory of the main headquarters of AB „Klaipėdos energija", a new construction 24 meters high appeared in 2023. It is a 3000 m^3 accumulation tank for the storage of cogeneration heat carrier. The project was carried out with the financial support of the EU and contributed to the improvement of the city's environmental situation and the reduction of heat prices.

Underneath the profiled sheet metal cladding is a 30 cm thick layer of insulation material to protect the main body from heat loss. One pipe is used to fill the tank with a thermal heat carrier up to 92°C, while the other pipe discharges it into the city's heat network as needed. The boiler house generates most of its heat from 4 boilers burning biomass fuel. But when the outside temperature is low, the heat produced by these boilers is no longer sufficient, and the gas boilers have to be fired up. A storage capacity of 3000 m^3 allows the company to store more heat from cheaper fuels and reduce the use of natural gas.

The experts who prepared the feasibility study for the project estimate that the savings in natural gas used for heat generation will amount to more than 15,000 megawatt hours (MWh) per year. From an environmental point of view, the storage capacity helps to reduce the greenhouse effect, with over 2,900 tonnes less carbon dioxide (CO_2) being emitted into the atmosphere each year.

ADVANTAGES

Klaipeda city has installed and is planning even more technological solutions leading towards decarbonization of the city district heating sector via the use of renewable energy, such as biomass, solar PVs and geothermal energy, as well as waste energy, as MSW incineration, waste heat energy from industry.

Klaipeda also seeks improvement of energy efficiency in the heating sector via the introduction of CHP technologies, condensing economisers and absorption pumps, as well as heat storage for biomass boilers.

LESSONS LEARNED

One of the important lessons is the possibility of using geothermal energy, which failed over two decades ago due to the lack of comprehensively implemented technological solutions. It is expected that this time, technological solutions will be selected more carefully.

A municipal waste incineration cogeneration plant must incinerate waste continuously (due to waste management and technological requirements). In summer, the heat demand in Klaipėda city is low, so almost half of the heat produced becomes excessive. There are also independent heat producers in the city, which compete for heat supply to the Klaipėda district heating network.

Installation of seasonal heat storage tanks would allow excess heat to be stored in summer and used later (e.g., during the transition period in autumn or winter). This would reduce heat emissions into the environment, increase the efficiency of the CHP, and reduce carbon dioxide and other harmful emissions into the air.

4.2.2 Kėdainiai District Municipality

GENERAL DATA

Population of the municipality: 45,425 (record of January 1, 2025)

Fig. 5. AB Panevezio energija, Kedainiai subsidiary (Photo by Panevezio Energija)

The activities of the company include :

- Heat generation, operation of consumers' heat and hot water systems;
- Heat is generated in 1 large district boiler-house in Kedainiai town, and 12 small boiler-houses, mainly in schools of smaller settlements and towns.
- Total thermal capacity of all boilers is 57.5 MW_{th}.
- The capacity of the PV plant – 0.099 MW_{el}.

Regional boiler-house of Kedainiai town has 4 water heating boilers with a total installed capacity of 46.52 MW_{th}. The main fuel here is natural gas, with reserve liquid fuel, mainly Diesel fuel.

Number of district heating consumers in the municipality: 328, in this:

- 261 residential buildings;
- 28 commercial buildings;
- 39 non-residential buildings (which are administrative buildings, such as banks, state and municipal institutions; educational institutions, such as schools. Kindergartens, vocational institutions. These also include cultural and sports institutions.

District heating network length(optional): approx. 46.14 km

Annual heat consumption in the district heating network (2023): own generation used to be negligible due to waste heat supply, but in 2023, the independent heat producer (industrial heat from Phosphorus fertiliser plant AB Lifosa) was under sanctions due to contacts with Russia. Currently, all heat in Kedainiai town is supplied from this plant as waste heat.

- Heat generation by AB "Panevezio energija", Kedainiai subsidiary: 81 400 MWh;
- Heat generation by independent heat producer (AB Lifosa): 18 900 MWh;
- Heat consumption: 90,100 MWh.

DESCRIPTION OF THE USED HEATING TECHNOLOGIES

Kedainiai DM is in a very special situation regarding district heating. District heating is supplied by regional DH company AB Panevėžio energija, Kėdainiai subsidiary. Total heat supply is approximately. 107 399 MWh and installed capacity 57.5 MW.

- AB Lifosa, since 2000, has used **process heat** emitted in the sulphuric acid production process for the heating of the company's and Kėdainiai city facilities. Owing to special steel tubular heat exchangers, the heat of sulphuric acid is transferred to water to raise its temperature to 90° C, and it is supplied to the Kėdainiai boiler house for the heating of residential buildings.
- Local boiler-house usually produces heat using natural gas; however, in usual conditions, this heat is not produced here as AB Lifosa provides all necessary waste heat to cover the needs of Kėdainiai town. It has not operated during heating seasons 2021-2023 (due to anti-Russian sanctions which caused low availability for natural gas).

Fig. 6. AB Lifosa (Photo by AB Lifosa)

- There is a small amount of **straw heat** produced at the Academy settlement (Institute of Agriculture), producing 5950.2 MWh of heat annually. However, these straw boilers are not efficient, and one of the two boilers is to be replaced by the **wood boiler** with an installed capacity of up to 2 MW of thermal energy.
- Existing biomass boilers with an installed capacity of 5.98 MW produce 7 300 MWh.
- The installed PV power plant meets the electricity needs of the boiler house for technological purposes and reduces the company's electricity costs. By increasing the use of renewable energy sources, the company contributes to solving environmental problems and reducing global warming. The 220 solar modules installed on the ground at the Kėdainiai boiler house will ensure the operation of a 99 kW PV plant, which can generate approximately 98 MWh of electricity per year.

ADVANTAGES

While the chemical plant AB Lifosa is operating in normal mode, industrial waste heat is supplied to the heat supply networks of the town of Kėdainiai, which satisfies more than 90 per cent of the total annual heat consumption. The plant has been operating without interruptions for the last two heating seasons.

The Kėdainiai district boiler house, with its available capacities, ensures full reservation of reserve heat production for the town of Kėdainiai.

In the south-eastern part of the town's territory, factories are being built in the rapidly growing free economic zone (industrial district), which could potentially generate an additional surplus of waste heat.

There are separate zones in the territory of Kėdainiai town where district heating networks could be expanded. One such zone is the complex of buildings of the Kėdainiai Town Hospital and several nearby multi-apartment residential buildings, a shopping centre, a school, and administrative buildings for other purposes. This district is close to the town's existing district heating networks.

LESSONS LEARNED

The use of close to 90% process waste heat, though it appears to be a very efficient and cheap source of heat, however, does not appear to be reliable in case of a *Force Majeure* situation. Such a situation may also be realistic in the case of bankruptcy and the closure of the industry.

To install seasonal heat storage tanks, which would allow for the accumulation of the excess waste heat generated at the Lifosa AB plant in the summer and use it later (e.g., during the transitional period in autumn or winter). This would reduce heat emissions into the environment, carbon dioxide and other harmful emissions into the air.

Due to the existing excess waste heat volumes in summer and during the period of low heat consumption, new solutions are needed. Consideration should be given to additional heat-consuming objects where the heat requirement would be during the non-heating season and at the beginning and end of the heating season. Such objects could be heated lawn stadiums, water treatment plants, and greenhouses for special purposes (adapted to the urban area)

With climate change and warming summer season periods, the application of absorption heat pumps that use heat to produce cooling can be technically and economically evaluated.

4.3 Best practices from Poland

4.3.1 Konin

GENERAL DATA

Population of the municipality: 65 359

Number of district heating consumers in the municipality: 2053

District heating network length(optional): 167 km

Annual heat consumption in the district heating network: 240 835,59 MWh

DESCRIPTION OF USED HEATING TECHNOLOGIES

The heating system in Konin is mostly powered by renewable sources (98%).

- **Konin Power Plant (currently PAK-PCE Biopaliwa i Wodór Sp. z o. o.):** since 2021, all heat production from this source is based on sustainable biomass. The total achievable capacity of heat exchangers is 175 MW, including 160 MW in cogeneration. In 2023, biomass production accounted for 98.24% of the fuel used for heat production at Konin Power Plant. The share of heat from cogeneration in this source is 99.67%.

- **Municipal Waste Management Plant Sp. z o.o. (MZGOK Sp. z o.o.):** The Municipal Waste Thermal Disposal Plant (ZTUOK), built in 2013-2015, has a capacity to process 94 000 tonnes of waste per year. In 2024, it produced 44 759 MWh of electricity and 180 206 GJ of heat. It has renewable energy source status. The share of heat from cogeneration at MZGOK is 95.03%.

- **The Geothermal Heating Plant in Konin:** completed in 2024, it will be the city's third heating source. The nearly PLN 66.5 million investment received over PLN 26.3 million in EU grants and PLN 18 million in loans from the National Fund for Environmental Protection and Water Management. It is located on Pociejewo Island, where hot springs were discovered with a record temperature of 94.5 degrees Celsius and a mineralization of 150 g/l. The water meets the parameters of medicinal water. The planned capacity of the geothermal unit is 8.1 MW, with an estimated annual production of approximately 159 000 GJ of heat. The geothermal heating plant will increase the use of renewable energy in Konin, supplying approximately 10% of the city's heating demand.

- **Gosławice Sugar Plant Boiler Room:** MPEC-Konin Sp. z o.o. operates a local boiler room with a capacity of 1.54 MW (total rated boiler capacity 1.5 MW), powering part of the Gosławice Sugar Plant estate. This is mostly an old radial network. The primary fuel used in the years 2020-2023 was hard coal. It is planned to change the fuel supply to biomass in near future.

The heating system consists of two main networks:

- **Network No. 1 (high-performance network)**: powered directly by the Konin Power Plant (PAK-PCE Biopaliwa I Wodór) and the ZTUOK (MZGOK). This is a water-based system operating at 130/71° C. Two heating mains, 2xDn 800 and 2xDn 600 (currently the Dn 600 is in reserve), extend from the Konin Power Plant. The network is over 165 km long. Over 56% of the total network length is pre-insulated. The system is primarily radial, but a portion is constructed in a ring configuration, ensuring reliable supply.
- **Network No. 2 (low-parameter network)**: supplying customers from the Gosławice Sugar Factory estate. It operates at 90/ 70° C. This is mostly an old network with a radial layout. There are no heating substations installed on this network. Network No. 2 is approximately 2 km long. Despite the condition of the pipelines, losses in this network are approximately 15-16%. In 2022, 10,203 GJ of heat from boiler rooms was introduced into Network No. 2.

The overall technical condition of the heating network is assessed as good, sometimes very good, thanks to the systematic replacement with a pre-insulated network and ongoing maintenance of all network components. MPEC-Konin Sp. z o.o. carried out a number of investments between 2021 and 2023 to increase the energy efficiency of the heating network. Telemetry in heat sources and heating networks is a key element of modern energy systems, enabling more efficient management, increased reliability, and cost reduction.

MPEC-Konin Sp. z o. o . is responsible for the transmission, distribution, and trade of heat in Konin.

In 2024, district heating sales totalled 229 638 MWh. As of 31. December 2024, the capacity ordered by customers decreased by 0.6785 MW compared to the end of the previous year.

As of the end of 2024, MPEC-Konin Sp. z o.o. had signed 2,049 comprehensive agreements with customers, and the number of metering points was 2,389. Following modernization, 60% of network no. 1 is now pre-insulated.

The heating system in Konin faces challenges due to its length and distance from heat sources, as well as the significant number of connected individual customers, which generates significant heat losses and long water delivery times to some customers. A noticeable factor requiring optimization is the excess of locally available thermal energy (MZGOK production – CHP and MPEC – geothermal heating plant), which will intensify considering the planned new sources (a second CHP source at MZGOK) in the cluster. The city of Konin cannot abandon heat from ZE PAK SA due to the capacity of the pumps supplying the system. Quantitative analyses show a gradual reduction in heat consumption in Konin.

ADVANTAGES

98% of the heat power supply is based on renewable energy. During annual maintenance work at ZE-PAK, the Municipal Waste Thermal Treatment Plant (incineration plant) is able to take over 100% of the heat supply to customers in Konin.

4.3.2 Lidzbark Warmiński

GENERAL DATA

Population of the municipality: 14 366 (2024)

Number of district heating consumers in the municipality: The described practice mentions 3,500 recipients using renewable heat (2024)

District heating network length(optional): not available

Annual heat consumption in the district heating network: 190 000 GJ for presented practice (2024)

DESCRIPTION OF USED HEATING TECHNOLOGIES

Ciepłownia Przyszłości (Heating Plant of the Future) in Lidzbark Warmiński is a demonstrator-scale installation developed by Euros Energy in cooperation with Veolia and financed under The National Centre for Research and Development programme. The demonstrator was commissioned in late 2023 and is currently being monitored and evaluated under real operating conditions. It supplies heat and domestic hot water to the Astronomów housing estate, which has a total residential usable floor area more than 28,000 m². The installed heat pump equipment is reported as 2.6 MW of high-efficiency heat pump capacity integrated into the plant. The plant's thermal-storage system is three-stage and includes a seasonal borehole thermal energy storage (BTES) built from roughly 300 boreholes and a water-tank PTES with an approximate volume of 15,000 m³. On-site renewable generation comprises a photovoltaic farm of about 1.26 MW and hybrid PVT collectors reported at roughly 190 kW. The demonstrator operates with modernized pre-insulated distribution piping and building heat nodes configured for distribution temperatures up to 80 °C. Project documentation describes the concept as scalable and suitable for replication in other small district-heating systems. Plant operator states that the demonstrator aims to supply the large majority of the estate's heat from renewable sources, with reported renewable shares for the serviced area above 90%.

ADVANTAGES

Ciepłownia Przyszłości (Heating Plant of the Future) in Lidzbark Warmiński shows how electricity from local renewable sources and seasonal thermal storage can provide a reliable low-carbon base for a small district-heating subnet. By combining high-efficiency electric heat pumps with on-site PV and PVT generation the plant reduces grid electricity imports and increases self-consumption of locally produced renewable energy. The large seasonal BTES and a high-volume PTES allow summer solar gains to be stored and discharged across the heating season, lowering reliance on fossil backup during winter. This storage-plus-heat-pump architecture enables effective peak shaving and reduces the need for rapid boiler ramping, which improves plant lifetime and operational stability. The demonstrator's modular and scalable design reduces replication risk for other small towns because the technical elements are proven in full-scale operation. Integrating thermal storage with flexible control also allows operational arbitrage where electricity prices vary, improving the overall economics of electrified heat. Using mostly on-site renewables and storage reduces exposure to fuel price volatility for the serviced estate and supports local energy security. The demonstrator reduces local combustion emissions at the estate level and provides a measurable example of near-zero local heat supply for a defined urban neighbourhood.

LESSONS LEARNED

Implementers must begin with rigorous geotechnical and thermal modelling to validate seasonal BTES performance and to size storage conservatively against multi-year variations. The plant architecture requires an integrated control system that synchronises PV/PVT generation, heat pumps and storage to optimise seasonal charging and operational dispatch. Project economics are sensitive to electricity price and availability, so investors should secure reliable access to low-carbon power sources and model price scenarios conservatively. Permitting for boreholes and large water tanks is technically demanding and time-consuming, therefore regulatory engagement and environmental assessment must be front-loaded. Phased commissioning with robust performance monitoring reduces technical and commercial risk and produces verifiable data that supports scale-up decisions.

4.3.3 Wrocław

GENERAL DATA

Population of the municipality: 672 882 (2024)

Number of district heating consumers in the municipality: 5960 (2024, number of district heating substations)

District heating network length(optional): 596 km (2024)

Annual heat consumption in the district heating network: 6.2 TJ (heating season 2023/2024)

DESCRIPTION OF USED HEATING TECHNOLOGIES

WROMPA is a municipal system heat-pump project in Wrocław designed to recover thermal energy from municipal wastewater and rainwater and to feed that heat into the district-heating network. The installation is a partnership between Fortum and the Municipal Water and Sewage Company (MPWiK) and is sited at the Port Południe sewage pumping station. The core of the project is a 12.5 MW system heat pump that will extract low-grade heat from wastewater flows and use that heat to produce hot water at a useful network level temperature. Construction works include deep diaphragm walls and substantial underground civil works required to house the pump and auxiliary equipment. The installation will be connected to the city network via a pipeline of roughly one kilometre in length with a reported pipe diameter on the order of 0.5 m. Project materials and press briefings report an expected annual thermal output on the order of 364,000 GJ, which is presented as covering roughly 5% of Wrocław's district-heating demand.

ADVANTAGES

The WROMPA installation demonstrates the advantage of harvesting waste heat from municipal wastewater and rainwater flows to heat up municipal water via a large system heat pump and then supplying this hot water to the district heating network. Recovering low-grade thermal energy at scale improves the city's overall energy efficiency by turning waste streams into a continuous, dispatchable heat source. By delivering a substantial continuous base output, the heat pump can displace part of coal-based heat production and thus reduce GHG emissions in the network. Locating the facility at an existing pumping station minimises new land take and leverages existing infrastructure for heat extraction and plant siting. Operating the heat pump with renewable electricity further increases carbon savings compared with fossil alternatives and improves lifecycle emissions performance. The WROMPA approach reduces dependence on imported fuels and therefore strengthens municipal resilience to fuel-price shocks. Large, centralized heat pumps also simplify maintenance logistics compared with many small boilers, leading to potential operation and maintenance cost advantages over time.

LESSONS LEARNED

A wastewater heat-pump project requires detailed characterisation of source streams, including temperature variability, solids content and fouling risk, as these parameters drive heat-exchanger and pretreatment specifications. The sizeable electrical load of a large system heat pump mandates early coordination with the distribution system operator and contingency planning for grid connection works. Civil works in sewage environments are complex and carry elevated schedule and cost risk, so thorough site investigation and close coordination with the water utility are essential. Heat-pump sizing and performance estimates should be conservative with respect to source temperature and hydraulic losses to preserve expected COP in operation.

4.3.4 Stargard

GENERAL DATA

Population of the municipality: 66 272 (2024)

Number of district heating consumers in the municipality: 793 (2025, number of district heating substations)

District heating network length(optional): 76.45 km (2025)

Annual heat consumption in the district heating network: 666 921 (2020)

DESCRIPTION OF USED HEATING TECHNOLOGIES

The geothermal system in Stargard (operated by G-Term / Geotermia Stargard) exploits deep geothermal waters with wellhead temperatures reported in the range of about 84–90 °C. Production wells for the project reach depths of roughly 2.6–2.7 kilometres, and the system uses a doublet approach with production and reinjection wells. Recent technical and industry reports indicate that seven geothermal wells are in operation at the site, including two main production wells. Published figures place the facility's annual geothermal heat production at roughly 180,000–200,000 GJ, making Stargard one of Poland's larger geothermal heat producers. Geothermal output is reported to supply more than 30% of the city's district-heating demand at present, with staged expansion planned to increase that share. The plant delivers produced geothermal water through heat exchangers into the district network and reinjects cooled water back into the reservoir to sustain resource performance. Technical summaries note high mineralization of the produced waters (on the order of 140–150 g/L), which dictates specific materials and filtration measures in the heat-exchange train.

ADVANTAGES

The geothermal system in Stargard provides a near-continuous, high-temperature base supply that stabilises the local district network and reduces the need for fossil-fuel baseload plants. Access to deep geothermal water at temperatures in the order of 80–90 °C allows direct heat delivery to the distribution network with limited additional boosting, which improves thermodynamic efficiency. The doublet production–reinjection scheme preserves reservoir pressure and sustainability, enabling reliable long-term operation without continuous resource depletion. Large annual geothermal production supplies a substantial share of the city's heat and reduces seasonal variability that peak plants must cover. The steady geothermal output reduces cycling of auxiliary boilers and lowers maintenance and fuel consumption for the whole system. Because the resource is local and continuous, it significantly reduces exposure to fuel price volatility and imports, strengthening local energy security. In addition, outside the main heating season, the geothermal system can supply Stargard with all the heat it needs. This allows traditional fossil fuel-fired combined heat and power plants to be shut down periodically, which facilitates maintenance of the entire system and reduces greenhouse gas emissions during the off-season.

LESSONS LEARNED

Deep geothermal development must be preceded by comprehensive reservoir characterisation and robust long-term performance modelling to avoid thermal drawdown and pressure issues. Reinjection strategy and reservoir management must be designed and contracted to preserve resource integrity over decades. High mineralisation of the produced water necessitates careful materials selection, filtration and scaling control, which materially affect both capital and operating expenditures. Drilling represents the principal technical and schedule risk, so staged drilling, experienced contractors and contingency budgets are essential.

4.3.5 Sokołów Podlaski

GENERAL DATA

Population of the municipality: 18 295 (2024)

Number of district heating consumers in the municipality: 194 (2015, number of district heating substations)

District heating network length(optional): 10 km (2015)

Annual heat consumption in the district heating network: 96 359 GJ (2015)

DESCRIPTION OF USED HEATING TECHNOLOGIES

Sokołów Podlaski hosts a prototype electro-thermal plant developed under the The National Centre for Research and Development programme that integrates upgraded biogas (biomethane), cogeneration and heat-pump technologies. The project uses biogas produced at an agricultural facility in Grochów Szlachecki; the biogas is upgraded to biomethane and transported by a dedicated pipeline to the plant. The plant couples cogeneration units (engines/generators with exhaust heat recovery) with water-to-water and high-temperature heat pumps and with buffer and peak-load equipment to provide flexible heat and power. Project reporting indicates the installation is capable of covering roughly 41% of the town's district-heating demand when the subsystems operate as designed. Public and trade sources report that the plant entered commercial operation in 2024. The facility was delivered by a consortium including Biogas East, ECN, Energotechnika, ICEB and the municipal company PUiK. Plant documentation specifies network parameters near 80/60 °C as the base design with capability to operate at lower distribution temperatures to reduce losses.

ADVANTAGES

The Sokołów Podlaski electro-thermal plant integrates upgraded biogas, cogeneration and heat-pump technologies to provide a high share of renewable primary energy for the local network. Using locally produced biomethane converts agricultural waste into dispatchable fuel for cogeneration units, improving circularity. Coupling CHP with heat pumps and buffer/storage enables flexible operation: the system can follow heat demand, shave peaks and prioritise renewable output when available. Supplying nearly half of the town's heating needs materially reduces reliance on conventional central boilers. Localised generation also shortens supply chains and reduces transmission losses compared with distant large-scale plants. Project documentation shows the system was designed to operate at network parameters that can be adjusted down to reduce distribution losses, improving overall system efficiency. The integrated plant acts as a site for practical testing of control strategies that coordinate CHP, heat pumps and storage, providing operational lessons for replication.

LESSONS LEARNED

Successful projects combining upgraded biogas, CHP and heat pumps start with securing long-term, quality-controlled feedstock contracts so the plant's fuel supply is predictable and reliable. Early engagement with local authorities and pipeline operators helps streamline permitting and ensures smooth delivery of upgraded gas to the site. Operational reliability depends on practical maintenance arrangements and ready access to spare parts and local service providers rather than distant specialists. The plant control strategy should remain straightforward, focused on meeting heat demand efficiently while making the best use of available renewable fuel and electrical flexibility.

4.4 Best practices from Finland

4.4.1 Tampere

GENERAL DATA

Population of the municipality: city of Tampere 260 400

Number of district heating consumers in the municipality: 6 037 households

District heating network length(optional): 659.3 km

Annual heat consumption in the district heating network: 2 207 GWh

The district heating network extends to a total of 5 municipalities, being on the border of two municipalities and covering the district heating consumption of three municipalities.

DESCRIPTION OF USED HEATING TECHNOLOGIES

The Tampere district heating system combines several complementary technologies to ensure secure, flexible, and efficient operation. Waste heat from waste incineration and datacentres cover the base load. After that, large electric boilers are used when wind power is abundant. Combined heat and power (CHP) remain important, as it produces electricity exactly when the power system is tight, complementing the flexible operation of e-boilers and storage. For peak and contingency situations, the system is designed for the "coldest, still week," ensuring demand can be met even if the largest plant is unavailable. Dispatchable capacity from fossil backup supports resilience. Thermal energy storage plays a vital role by shifting heat between hours and days, improving both economics and operational stability.

Evidence of Tampere's long tradition of fair and motivating district-heating tariffs goes back at least to 2012, when Tampereen Energia received Finland's "Fair District Heating Company" award. The jury praised the utility's proactive, trust-building approach—including checking customers' contract flow rates unprompted and consulting them when renewing its pricing model—showing enduring commitment to transparent, customer-oriented tariffs.

Tampere also has a district cooling system. Tampere's district cooling network draws naturally cold deep water from Lake Näsijärvi and distributes the cool via underground piping to buildings. Most of the year it operates with free cooling from the lake; when summer warms the water, chillers powered by renewable electricity take over—providing a quiet, low-carbon way to keep properties comfortable.

ADVANTAGES

This integrated approach to district heating provides high reliability during extreme conditions while simultaneously enhancing the flexibility of the overall energy system. Electric boilers and heat pumps enable the uptake of surplus renewable energy, while thermal energy storage smooths operations and supports cost efficiency. CHP plants provide not only heat but also electricity at critical times, strengthening the power system. Moreover, the system creates opportunities for lowering emissions and even achieving net-negative results when coupled with carbon capture on bio-based generation.

LESSONS LEARNED

- Systems must be engineered to withstand cold, still periods and unexpected outages.
- Dispatchable backup capacity remains essential, as electric boilers alone cannot guarantee supply.
- The district heating system was originally created to utilize waste heat from electricity production. In the future, the waste energy from excess wind power, datacentres and hydrogen production is the key to a competitive heating system.

4.5 Best practices from Sweden

4.5.1 Kalmar

GENERAL DATA

Population of the municipality: 73 000

Number of district heating consumers in the municipality: Approximately 2 500 households

Annual heat consumption in the district heating network: Approximately 360 GWh.

The CHP facility, in addition, produces approximately 130 GWh annually. The electricity production is equivalent to about one third of Kalmar's electricity demand. The main boiler is rated at 90 MW thermal and the steam turbine has a rated electricity production of 31 MW.

DESCRIPTION OF USED HEATING TECHNOLOGIES

There are two facilities owned by the district heating providing company "Kalmar Energi". The Moskogen CHP plant, the main facility, was built and commissioned in 2009. It accounts for approximately 85 % of the total fuel supply to the two facilities. The technology used for this primary production is a bubbling fluidized bed, BFB. Moskogen is located approximately 12 km outside the city centre of Kalmar. The investment for the BFB in Moskogen entailed an investment in the extension of the grid for the heat transfer to the city. The water in the heat pipes can go up to 115°C. The heat loss along the pipeline is small due to good insulation.

The three main sources for covering the base heat load are wood chips from branches and tops from harvesting areas, bark and sawdust. Fossil liquid oil accounts for less than 1 percent of the total energy in the fuel mix. The use of fossil fuel is limited to seasonal start-ups or unforeseen operating situations.

At the Moskogen facility, there is an atmospheric accumulator tank that equalizes the heat demand and maintains pressure in the district heating network. The volume of this tank is 21 600 m³, height 56 m.

For the flue gas treatment SNCR is used for NO_x control. There is an electrostatic filter and, in addition, a flue gas condenser with air humidification. Furthermore, a flue gas/water condensate treatment is installed.

All ash produced is recycled. It is returned to forests, to supply nutrients. Bottom ash is used for purposes like roadbuilding where appropriate.

ADVANTAGES

The obvious advantage for this co-generation facility, is the production of electricity. There is a need of more electricity production in southern Sweden, since most of the installed power are located to the northern parts of the country, e.g. large-scaled hydro power, while most of the inhabitants are living in the south.

A significant advantage is the possibilities for various types of fuels or biomass fractions in the supply mix. During the past years with un unstable and unpredictable development of energy markets, and an unforeseen increase at the prices for solid biomass, it is an important advantage to get the flexibility in the supply mix. This possibility entails consequently lower costs for the supplied energy.

A bubbling fluidized bed secures an efficient transfer of heat, and it is, among several other advantages, easy to maintain and operate.

LESSONS LEARNED

The technology is not an option when the heat needed is small – the investment costs are considerably high.

The quality of the sand in the bed is crucial for the heat transfer, and the temperature must be kept quite precise and stable in order to avoid unfortunate consequences.

4.5.2 Southern Sweden merger of district heating networks

GENERAL DATA

Population of the area:

- Lund: 98 308
- Lomma: 13 699
- Eslöv: 15 598
- Landskrona: 33 372
- Helsingborg: 113 816

Annual heat consumption of the area:

- Skåne region (including Lund, Eslöv): approximately 2500 GWh

DESCRIPTION OF USED HEATING TECHNOLOGIES

In southern Sweden there is an outstanding example of an integrated district heating network that extends across several municipalities. The network is a collaborative effort involving Kraftringen, Landskrona Energi, and Öresundskraft. These companies work together to optimize energy production and distribution across the region. The network connects the cities of Lund, Lomma, Eslöv, Landskrona, and Helsingborg, creating an integrated system that enhances energy efficiency and reliability. The district heating is mainly produced from fossil-free and recycled energy sources, including industrial waste heat, waste and renewable biofuels. This example shows how cooperation between municipal energy companies can lead to efficient and sustainable energy solutions that benefit both the environment and the economy.

Located in Örtofta, Kraftringen's CHP plant is a central facility in the network. It produces both electricity and heat from renewable biofuels, significantly reducing carbon emissions. In Lund's Brunnshög district, Kraftringen has developed the world's largest low-temperature district heating network. This system operates with supply temperatures of 65°C and return temperatures of 35°C, utilizing advanced plastic piping for efficient heat distribution. The network taps into excess heat, as well as geothermal water and aquifers, to provide sustainable heating solutions.

Building different district heating networks together — that is, creating an interconnected network between several municipalities or energy companies — has several technical, economic and environmental advantages.

ADVANTAGES

Environmental and climate benefits

- Reduced emissions: Collaboration makes it possible to prioritize fossil-free and renewable sources throughout the network.
- Better resource use: Waste heat from industries or CHP plants in one city can be used in another.
- Greater share of biofuels: District heating production can be coordinated so that biofuel-fired boilers have a greater share of operation.

Increased operational reliability and flexibility

- Reserve capacity: If a production plant experiences a breakdown, heat can be supplied from another connected plant.
- Flexible load balancing: Energy consumption can be spread across larger areas, reducing the load on individual boilers and systems.

Economic benefits

- Reduced operating costs: Through optimized control, fuel consumption and maintenance costs.
- Facilities to secure peak load and reserve production may be reduced to a smaller number of plants.
- More efficient production: Heat can be produced where it is cheapest or most efficient at the moment, e.g. in a high-efficient combined heat and power plant.
- Larger volumes of purchased fuel provide a better negotiating position with fuel suppliers
- Joint investments: Expensive facilities (e.g. bio-boilers or accumulators) can be shared between municipalities.

Regional social benefit

- Innovation and development: Collaboration between companies drives technology development, such as low-temperature networks and heat storage.
- Strengthened energy supply: More municipalities gain access to a robust and sustainable heat supply.
- Enables urban development: New areas can be more easily connected to the existing network through proximity to a larger shared infrastructure.

5 Analysis of the best practices

5.1 Common traits of advantages

The integration of renewable energy sources is a key feature in modern heating strategies. By utilizing biomass, solar photovoltaics (PVs), and geothermal energy, district heating systems can substantially reduce greenhouse gas emissions. This shift not only aids in decarbonization efforts but also enhances the resilience of energy supply. Furthermore, employing waste energy, including municipal solid waste incineration and heat recovery from industrial processes, maximizes resource utilization while minimizing environmental impacts.

Energy efficiency is another crucial trait observed in successful district heating networks. The adoption of combined heat and power (CHP) technologies allows for simultaneous electricity and heat generation, thereby improving overall system efficiency. Such technologies capitalize on the waste heat produced during electricity generation, delivering additional benefits to the heating supply. Moreover, the integration of condensing economizers further contributes to energy efficiency by capturing and reusing waste heat, reducing energy consumption in the process.

Additionally, the utilization of absorption pumps plays a fundamental role in optimizing energy flows within district heating systems. These pumps can effectively utilize low-grade heat, enhancing the overall heat recovery capabilities. This approach aligns with the broader objective of maximizing energy efficiency while utilizing diverse energy sources, which is critical in achieving sustainability goals.

Heat storage systems also exemplify good practices in district heating networks. Implementing heat storage for biomass boilers allows for the balancing of supply and demand, facilitating the use of renewable energy when available. This flexibility is particularly important given the intermittent nature of certain renewable sources, such as solar and biomass. By storing excess heat for later use, district heating networks can ensure stable heating supply throughout varying demand periods and enhance system reliability.

The collaboration with industrial sectors can further enrich district heating networks. Utilizing the waste heat generated by manufacturing and chemical processes provides an additional energy source that complements renewable initiatives. This integration not only supports the heating network but can also bolster the economic viability of industrial operations by reducing energy disposal costs.

Overall, the positive effects of implementing these good practices in district heating networks are numerous. They lead to enhanced sustainability, reduced reliance on fossil fuels, increased energy efficiency, and improved overall economic conditions for both municipalities and industries. By continuously advancing these practices, cities can better meet their energy demands while progressing towards a more sustainable future, ensuring that heating systems remain reliable, cost-effective, and eco-friendly. The concerted efforts to embrace innovative technologies and renewable resources will pave the way for a transformative shift in urban energy consumption.

5.2 Common traits of lessons learned

In analysing the lessons learned from district heating developments, particularly in the context of renewable energy and resource utilization, several important insights emerge. A significant lesson revolves around the potential of geothermal energy for district heating systems. Despite initial setbacks over two decades ago, attributed to inadequate technological solutions, there is cautious optimism that contemporary advancements will make geothermal implementations viable. This expectation underscores the importance of thorough planning and careful selection of technologies to ensure successful integration into energy systems.

The operation of municipal waste incineration cogeneration plants highlights another critical lesson. These facilities are designed to operate continuously, which is essential due to regulatory waste management requirements. However, they often generate excess heat during periods of low demand, notably in the summer months. This excess heat, which can account for nearly half of the output, represents a missed opportunity in terms of resource efficiency. The recognition of this pattern necessitates innovative solutions, such as the installation of seasonal heat storage tanks. Such systems would enable the storage of surplus heat during low-demand periods for later use in the colder months, effectively reducing environmental emissions while enhancing overall system efficiency and reliability.

The reliance on waste heat, particularly from industrial processes, serves as another focal point in these lessons learned. While nearly 90% process waste heat offers a seemingly abundant and cost-effective source of energy, it poses reliability risks during unforeseen circumstances, such as plant closures or economic downturns. Hence, diversifying heat sources and supply chains becomes imperative. Seasonal heat storage tanks present a viable solution to help manage this variability by capturing excess industrial heat for later use. This approach not only mitigates emissions but also lessens pressure on the heating supply during peak demand periods.

Moreover, exploring additional heat-consuming applications during non-heating seasons provides an avenue for optimizing resource utilization. Ideas such as using surplus heat for heated sports facilities, specialized greenhouses, or water treatment plants are promising and demonstrate an adaptive approach to managing heat supply and demand.

Adapting technologies in response to climate change is also paramount. The implementation of absorption heat pumps, which can convert heat into cooling, represents a dual-purpose solution that not only addresses heating needs during winter but also cooling requirements in warmer months, making it an economically valuable option.

Comprehensive planning and project management are critical takeaways from previous experiences as well. Technologies require thorough geotechnical and thermal modelling to validate performance and ensure appropriate sizing. This level of careful assessment extends to the integration of renewable sources, necessitating advanced control systems that can synchronize various technologies, such as solar energy generation and heat pumps, to optimize efficiency and operational throughput.

Furthermore, permitting processes for geothermal projects and the installation of substantial heat storage tanks must be considered early in project planning due to their complexity and time-consuming nature. Engaging with regulatory authorities and conducting detailed environmental assessments upfront can streamline these processes and reduce project risks.

Lastly, successful projects in heat management hinge upon creating reliable and predictable systems. This includes securing long-term contracts for feedstock in biomass and ensuring that operational strategies focus on efficiency and sustainability. In doing so, projects must be resilient to unexpected disruptions while maintaining flexibility in operations.

Ultimately, the journey of enhancing district heating systems through renewable and efficient practices is one of continuous learning. By acknowledging past challenges while innovatively addressing current and future needs, stakeholders can contribute to a sustainable and efficient energy landscape for urban environments.

5.3 Important notices and conclusions

The exploration of common traits and lessons learned in the context of district heating networks reveals several important conclusions that can shape future developments and strategies in urban energy systems.

Firstly, the integration of renewable energy sources, particularly geothermal energy, presents a significant opportunity for enhancing sustainability. The earlier failures in geothermal implementations highlight the necessity for careful technology selection and comprehensive planning. These lessons remind stakeholders to adopt a strategic approach that considers both technological advancements and sustainable practices.

Additionally, the operation of municipal waste incineration cogeneration plants unveiled the challenges associated with managing heat supply amid fluctuating demand. The observation that excess heat production occurs during low-demand periods, especially in summer, provides an insightful lesson for optimizing energy efficiency. In particular, the implementation of seasonal heat storage tanks could serve as a critical solution. By capturing and storing surplus heat, municipalities could effectively balance supply with demand throughout the year, reducing environmental emissions and enhancing system efficiency.

Furthermore, the competition among independent heat producers for supply to district heating networks illustrates the complexities inherent in energy markets. This situation calls for collaborative frameworks that can facilitate resource sharing and more efficient energy distribution.

In conclusion, the lessons learned from both the advantages and challenges of district heating networks underscore the importance of sustainable practices, innovative technological solutions, and careful planning. By addressing these factors, cities can create resilient and efficient heating systems that not only meet current demands but also contribute positively to the broader goals of environmental sustainability and energy security.

Key Conclusions:

- **Leveraging Renewable Energy**: Emphasizing geothermal energy and other renewables as central components of district heating can lead to greater sustainability.
- **Careful Technology Selection**: Lessons from past geothermal projects underscore the importance of a meticulous evaluation of technologies to increase success rates.
- **Continuous Operation of Cogeneration Plants**: Municipal waste incineration facilities and combined heat and power plants must be technically supported with other technical solutions, like thermal energy storages, heat pumps and power-to-heat technologies, to ensure efficient operation, even during periods of low demand.

- **Addressing Seasonal Demand Fluctuations**: The installation of seasonal heat storage tanks can effectively mitigate excess heat production and enhance overall system efficiency.

- **Strategic Planning**: A comprehensive approach that considers both technological and environmental factors is essential for future developments in district heating networks.

These conclusions provide a roadmap for stakeholders aiming to enhance the efficiency and sustainability of district heating systems, ultimately contributing to a more resilient energy future.