

<b>Project no.:</b>	<b>STHB.02.01-IP.01-0009/23</b>
<b>Project full title:</b>	<b>Decarbonization of district heating systems</b>
<b>Project Acronym:</b>	<b>DecarbonDHS</b>

Deliverable number:	<b>D2.1</b>
Deliverable title:	<b>Assessment of the existing heating infrastructure, energy mix (energy sources), efficiency, and carbon emissions</b>
Work package:	WP2
Due date of deliverable:	M18
Start date of project:	01/07/2024
Duration:	36 months
Author/editor:	Dr. Yannik Schütze (YS)
Contributing partners:	IMP PAN, OPEC, IWEN, KDH, KM, BEOF, LNU



This deliverable is co-financed from the Interreg South Baltic Programme 2021-2027 through the European Regional Development Fund. (Project: DecarbonDHS, STHB.02.01-IP.01-0009/23). The content of this deliverable is the sole responsibility of its authors and can under no circumstances be regarded as reflecting the position of the European Union, the Managing Authority or the Joint Secretariat of the Interreg South Baltic Programme 2021-2027.

## Document history

Version no.	Date	Authors	Changes
0.1	19.11.2025	YS	Initial draft
0.2	12.12.2025	MD	Addition to subchapter 3.1.2
0.3	19.12.2025	YS	Small corrections

## Contributors

Partner no.	Partner short name	Name of the Contributor	E-mail
LP	IMP PAN	Mieczysław Dzierzgowski Adam Cenian	<a href="mailto:Mieczyslaw.dzierzgowski@pw.edu.pl">Mieczyslaw.dzierzgowski@pw.edu.pl</a> <a href="mailto:cenian@imp.gda.pl">cenian@imp.gda.pl</a>
PP2	OPEC	Grzegorz Glowacki	<a href="mailto:g.glowacki@opecgdy.pl">g.glowacki@opecgdy.pl</a>
PP3	IWEN	Yannik Schütze Jonathan Aschenbrenner	<a href="mailto:y.schuetze@iwen-energy.org">y.schuetze@iwen-energy.org</a> <a href="mailto:j.aschenbrenner@iwen-energy.org">j.aschenbrenner@iwen-energy.org</a>
PP5	BEOF	Christian Nygaard Sorensen Jonathan Møller	<a href="mailto:cns@beof.dk">cns@beof.dk</a> <a href="mailto:jom@beof.dk">jom@beof.dk</a>
PP6	KDH	Farida Dzenajavičienė	<a href="mailto:farida.dzenajaviciene@lei.lt">farida.dzenajaviciene@lei.lt</a>
PP7	KM		
PP8	LNU	Leteng Lin	<a href="mailto:leteng.lin@lnu.se">leteng.lin@lnu.se</a>

## Table of Contents

1	Executive Summary .....	6
2	Methodology.....	2
2.1	Overall Approach: Collaborative framework for cross-partner analysis.....	2
2.2	Analytical Frameworks: Shared Metrics.....	2
3	Assessment analyses .....	4
3.1	IMP PAN: Łomża – Poland .....	4
3.1.1	The district heating system in ŁOMZA operated by “MPEC Łomża” .....	4
3.1.2	Decarbonisation of Łomża DH system.....	8
3.1.3	Summary.....	11
3.2	OPEC: Wejherowo – Poland.....	12
3.2.1	Technical Specifications of heating system in Wejherowo .....	15
3.2.2	Environment and biodiversity .....	17
3.2.3	Conclusions and Outlook .....	18
3.3	BEOF: Bornholm – Denmark .....	19
3.3.1	Introduction.....	20
3.3.2	Historical Development .....	20
3.3.3	System overview .....	21
3.3.4	Digital control and monitoring.....	22
3.3.5	Storage and flexibility .....	23
3.3.6	Optimization initiatives .....	24
3.3.7	Innovation and future strategy.....	24
3.3.8	Conclusions and outlook .....	25
3.4	KDH/KM: Kretinga – Lithuania .....	25
3.4.1	Introduction.....	27
3.4.2	Technical Specifications of Kretinga District Heating company.....	27
	Heat supply and fuel structure (data for year 2023) .....	28

---

Installed capacities .....	29
Operating parameters .....	34
Digitalization and monitoring .....	34
3.4.3 CO <sub>2</sub> Emissions .....	35
3.4.4 Inefficiencies and Improvements.....	35
3.4.5 Conclusions and Outlook .....	35
3.5 IWEN: Rostock – Germany .....	36
3.5.1 Introduction.....	38
3.5.2 Technical Specifications of DHS Rostock.....	38
3.5.3 CO <sub>2</sub> Emissions .....	41
3.5.4 Inefficiencies and Improvements.....	42
3.5.5 Conclusions and Outlook .....	43
3.6 LNU: Kosta – Sweden.....	44
3.6.1 CO <sub>2</sub> Emissions.....	45
3.6.2 Energy inefficiencies .....	45
3.6.3 Measures to improve efficiency.....	46
4 Conclusions and Outlook .....	47
5 Bibliography .....	49



# 1 Executive Summary

---

This report provides a comprehensive technical assessment of six diverse district heating systems – Łomża, Wejherowo, Bornholm, Kretinga, Rostock, and Kosta. It evaluates their current infrastructure, energy mix, operational efficiency, and emissions, as well as ongoing modernization efforts. The findings reveal a spectrum of development stages: from mostly decarbonized, biomass-fueled networks to large fossil-based systems in need of transformation. Common themes include efforts to reduce heat losses, integrate renewable energy, and prepare for deeper decarbonization. Below is a summary of the key results for each system:

- Łomża (Poland)** – The Łomża DHS has significantly improved its efficiency and shifted its fuel profile in recent years. Originally a 100% coal-fired system with high supply temperatures (121 °C) and about 16% network heat losses, Łomża undertook extensive modernization. By 2022, supply/return temperatures were lowered (to ~97/64 °C) and losses cut below 11%. Coal's share in heat production fell from 100% to just 10.6% as biomass and gas were introduced. As of 2024, 72.5% of heat is supplied by biomass (with the remainder from coal). These changes have reduced carbon emissions and improved overall system performance. Key measures included cleaning and upgrading over-sized substations (many were 2–7 times over-capacity) and adjusting hydraulic regimes to achieve lower return temperatures and better  $\Delta T$ , thereby increasing efficiency. Łomża's case demonstrates how legacy networks built for larger demand can be right-sized and partially decarbonized through targeted technical interventions and fuel switching.
- Wejherowo (Poland)** – The Wejherowo network is a mid-sized system (approx. 44 km of pipelines) currently fueled by a mix of natural gas and coal. A central heat plant with coal-fired boilers is supplemented by a gas CHP engine (6.8 MW<sub>el</sub>). The system operates at 108 °C/55 °C supply/return and has pipe heat losses around 15.4%, indicating moderate efficiency for its age. Past upgrades improved reliability, and environmental initiatives (such as on-site solar panels, beehives and bird nesting programs) reflect a broader sustainability commitment. In 2024, the operator OPEC Gdynia adopted a Climate Neutrality 2050 Plan for Wejherowo's DHS. This decarbonization roadmap includes phasing out coal boilers and adding low-emission technologies: a solar thermal farm, a large heat accumulator, new biomass boilers (including converting an existing coal unit to wood pellets), high-efficiency gas/oil peak units, an electrode boiler, and waste-heat recovery from the gas CHP. These planned investments will gradually cut emissions and diversify the energy mix away from coal. In the meantime, Wejherowo's system provides secure heat supply to roughly half the city's residents, and ongoing operational optimizations aim to further reduce losses and improve substation performance. The groundwork is being laid for a transition from the current coal/gas mix to a more sustainable heat supply over the coming decades.
- Bornholm (Denmark)** – The district heating network on Bornholm is an island-wide system spanning about 260 km and delivering ~160 GWh of heat per year. Operated by BEOF, it serves ~6,700 customers across several towns. The energy mix is almost 100% renewable, dominated by locally sourced biomass: roughly 77% wood chips and 22% straw. This biomass-based supply is officially considered carbon-neutral, though it produces an estimated 50,000 tons of biogenic CO<sub>2</sub> annually. System efficiency is a focal point for Bornholm. The DHS already employs large thermal storage (over 12,000 m<sup>3</sup> of hot water, ~900 MWh) to buffer peaks, and island-wide smart metering. Advanced digital tools enable detailed monitoring and optimization. One ongoing initiative is the Cooling Improvement Project, which aims to lower return temperatures from ~43–45 °C down to 35 °C by 2028. By improving  $\Delta T$  and encouraging consumers to return cooler water (through new tariff incentives), BEOF intends to reduce distribution losses and unlock additional capacity. Asset

management is proactive – about 57% of the network pipelines have been renewed in recent expansions, and remaining older sections (e.g. in Nexø and other towns) are prioritized for reinvestment due to high return temps or corrosion issues. In summary, Bornholm’s DH system is a renewables-driven, modern network with robust efficiency measures, though its reliance on biomass as a transitional fuel is acknowledged. Plans are in place to pilot innovative solutions (smart thermostats, demand response, surplus wind-to-heat integration) to further decarbonize in line with Denmark’s climate goals.

- Kretinga (Lithuania)** – The Kretinga district heating company operates a decentralized network in and around Kretinga town, supplying ~3,567 consumers in over 250 buildings. Heat is produced by a fleet of 28 small boiler houses distributed across the area. Over the past two decades, Kretinga transitioned dramatically from natural gas to biomass. By the mid-2000s it was among the first in Lithuania to achieve ~90% biomass in its fuel balance, utilizing wood waste (wood chip pellets) as the primary fuel. This shift, combined with installation of multi-cyclone dust filters and a condensing economizer (added in 2011), has improved combustion efficiency and cut particulate emissions by ~87–90%. The current biomass-centric supply means the reported CO<sub>2</sub> emissions are near-zero – indeed, official GHG inventory for 2023, verified by DNV, recorded 0 tonnes CO<sub>2</sub> for Kretinga’s main biomass boiler plant. In terms of infrastructure, the network consists of about 20 km of pipelines (over half have been modernized to pre-insulated pipes). Ongoing upgrades focus on replacing remaining old pipelines (the main source of heat loss) and encouraging building renovations on the demand side. Thanks to these efforts, recent pipeline retrofits (e.g. 1.6 km main line in 2020) have improved reliability and reduced distribution losses by ~240 MWh/year. Overall, Kretinga’s DHS is now a low-emission, biomass-fueled system with improving efficiency. Key future tasks include completing network refurbishment and implementing remote monitoring in substations to further optimize operations.
- Rostock (Germany)** – Rostock operates one of the largest and most established DHS in this study, with roughly 421 km of pipelines and 576 MW of installed load. The system supplies about two-thirds of the city’s households (on the order of 78,000 customers) and delivers 700–750 GWh of heat annually. Rostock’s heat supply remains primarily fossil-fueled. The main source is a gas-fired CHP plant (combined-cycle turbine) at Marienehe which provides ~70% of the heat (while also generating electricity). Another ~150 MW of heat (about 20–30% of annual supply) comes as industrial “waste heat” from a coal-fired power station at the port. Officially, this reclaimed heat is assigned an emission factor of 0 g CO<sub>2</sub>/kWh, which yields a deceptively low certified value of 132.8 g/kWh for the delivered district heat. In reality, if the coal plant’s emissions are considered, Rostock’s DHS has one of the highest CO<sub>2</sub> footprints among the cases – highlighting a major decarbonization challenge. The network operates at a high temperature regime (winter supply up to 125 °C, return ~60 °C) and medium pressure (6–10 bar). These parameters have been suitable for integrating large CHP and waste-heat sources, but they constrain the immediate integration of low-temperature renewables (e.g. industrial heat pumps or geothermal) without substantial system modifications. On a positive note, Rostock’s municipal utility company has recently invested in enhancing flexibility and efficiency: a new 2 GWh hot-water storage tank is now operational, enabling load shifting and peak shaving, and an electric power-to-heat unit has been commissioned to utilize excess renewable electricity in the grid for heat production. Furthermore, a 33 GWh pit thermal energy storage is planned to be built within the next years. The system is technically robust and delivers reliable service, but strategically it is at a crossroads – substantial infrastructure and fuel strategy changes will be required for the city to meet its climate-neutral heat supply target by 2035.

- **Kosta (Sweden)** – The Kosta district heating system is a small rural network centred on a single modern biomass heating plant (approx. 3 MW capacity). It has achieved near-complete decarbonization of heat supply. The Kosta plant is fueled by wood chips and equipped with a state-of-the-art flue gas condenser (a centrifugal scrubber) to capture waste heat. By condensing moisture from flue gases, the plant boosts its thermal efficiency by up to 20–25% (on a lower heating value basis). In a recent year-long assessment, about 2.3 GWh of extra heat was recovered thanks to this condenser, allowing a corresponding fuel saving of ~1,500 tons of wet biomass (45% moisture). As a result, Kosta’s network operates with very low losses and the boiler often runs at reduced loads, yet still meets demand. The supply is entirely renewable and even the electricity for pumps/controls is “green,” so the facility is officially carbon-neutral. Presently, the main inefficiencies lie in the distribution grid and end-use: further transitioning to lower-temperature distribution could cut the already modest heat losses, and varying insulation levels in older buildings mean some heat demand could be avoided with building retrofits. Looking ahead, the Kosta system is exploring poly-generation opportunities – for example, integrating an Organic Rankine Cycle to produce electricity from excess heat, or producing biochar as a byproduct, which could sequester carbon and improve fuel utilization. Smart control strategies (AI-based demand forecasting tied to the network model) are also being considered to optimize supply in real-time. In summary, Kosta stands as a model small-scale DHS, demonstrating how biomass and advanced heat-recovery technology can yield a zero-emission heat supply. Further efficiency gains and innovation integration will aim to maintain its carbon-neutral status while improving economic performance.

Overall, across the six systems, technical performance is improving and carbon intensity is generally trending downward. Four of the networks now source a majority of heat from renewable biomass, dramatically cutting direct fossil CO<sub>2</sub> output. Measured heat losses in distribution range from around 10–15%, with several networks managing to push losses into the low teens or single digits through insulation upgrades and optimized operation. Supply/return temperature levels vary but most are gradually being reduced – a key strategy to improve efficiency and enable future low-temperature heat sources. Each system has a tailored modernization program, from infrastructure retrofits to digitalization and integration of thermal storage. These efforts provide a strong foundation for the next project phase, where strategies for incorporating renewable energy sources will be developed for each district heating system.

Location	Country	Length [km]	Installed Load [MW]	No. Customers	Temperature [°C]		Pressure Level [bar]		Heat Sources	Pipe Losses [%]	Pipe diameters [mm]	Network Design	Storage Capacities [m <sup>3</sup> ]	Power Density [MW/km]
					Flow	Return	Supply	Return						
Łomża	Poland	82.2	155	923 substations	93 – 110	50 – 96	6.8	4.4	3 CHP biomass HP gas fired HP coal fired	11	25 – 600	Radial with 8 rings	-	1.5
Wejherowo	Poland	37.4	48.8	443 substations	108	55	7.6	5.3	2 CHP gas fired HP coal fired	15.6 – 61.5	25 – 3500	Radial	1,801	1.47
Bornholm	Denmark	260	81.1	6722	>80	43 – 45	-	-	Multiple decentralized biomass plants	~26	170/450	Decentralized, zone-based mixed urban/rural structure	12,000	0,3
Kretinga	Lithuania	20.2	55.6	3900 consumers 66 % residents 26 % public institutions 8 % business	95	41	5	3	28 ~88.6 % biomass, ~10.6 % natural gas, 0.8 % LPG	17.2	-	Mixed load control	-	2.6
Rostock	Germany	421	576	78,000 (2/3 of all private households)	70 – 130	<60	13	7 – 12	2 ~70 % natural gas, 29 % hard coal, <1 % RE	-	-	Main line with various branches	45,000	1.4

Kosta	Sweden	10	3	200 private households, 19 community buildings, 14 housing company buildings, 2 hotels	85	45	3.5	-	1 biomass fired	7 – 11	25 – 150	Traditional	-	0.3
-------	--------	----	---	--	----	----	-----	---	-----------------	--------	----------	-------------	---	-----

## 2 Methodology

---

### 2.1 Overall Approach: Collaborative framework for cross-partner analysis

To ensure consistency in assessing the six district heating systems, the project consortium adopted a collaborative framework that harmonized methodologies across all partner analyses. Seven partner organizations – including utility companies, municipal agencies, and research institutions from Poland, Denmark, Lithuania, Germany, and Sweden – worked in close coordination. A unified assessment approach was co-developed through cross-partner workshops and regular technical meetings. This ensured that each case study was evaluated under a common set of criteria and procedures, facilitating meaningful comparisons.

At the project outset, the consortium agreed on a structured outline for the local assessment reports. Each partner gathered detailed information on their DHS's infrastructure (network length, number of customers, capacity, etc.), operational parameters (temperatures, pressures, losses), fuel supply mix, and environmental performance. By using shared definitions and units, partners ensured data was directly comparable from one system to another.

Cross-partner coordination was maintained throughout the assessment process. The consortium established a schedule of virtual meetings and exchanges to discuss progress, address data gaps, and refine methodologies collaboratively. Certain software tools were utilized by multiple partners – for example, several teams employed network modelling or monitoring systems as part of their analysis, and their experiences were exchanged to improve overall outcomes. Additionally, the partners conducted peer reviews of each other's chapter drafts, offering feedback to align the depth of analysis and to ensure that important factors were consistently covered.

### 2.2 Analytical Frameworks: Shared Metrics

In order to compare performance and characteristics across the six case-study heating systems, the project defined a set of shared technical metrics. These common indicators formed an analytical framework that every partner used in evaluating their system. By measuring and reporting the same parameters – from temperatures to emissions – the consortium could directly contrast different networks and identify areas for improvement. The key metrics and indicators included:

- **Supply and Return Temperature Levels:** Each system documented its typical operating temperatures for supply (flow) and return water. This metric indicates whether a network runs as a high-, medium-, or low-temperature system, which affects its efficiency and the potential to integrate low-carbon heat sources. Comparing these figures helped identify which systems could benefit from temperature reduction strategies. A lower supply/return temperature difference (while meeting demand) is generally desirable, as it implies better utilization of heat and lower losses. Several case studies highlighted efforts to reduce temperatures over time.
- **Network Heat Losses:** All partners evaluated the percentage of heat lost in distribution (pipes and substations) relative to total heat supplied. This is a critical efficiency metric for district heating. Older or over-sized networks tend to have higher losses, while modern, well-insulated pipelines

keep losses low. By using this common metric, the project could benchmark each system's infrastructure efficiency and set targets for loss reduction. It also enabled estimating how much fuel savings could be achieved by insulating or replacing pipes. Notably, the analyses underscored that even systems with already "low" losses consider further reductions important, especially if they transition to lower temperatures.



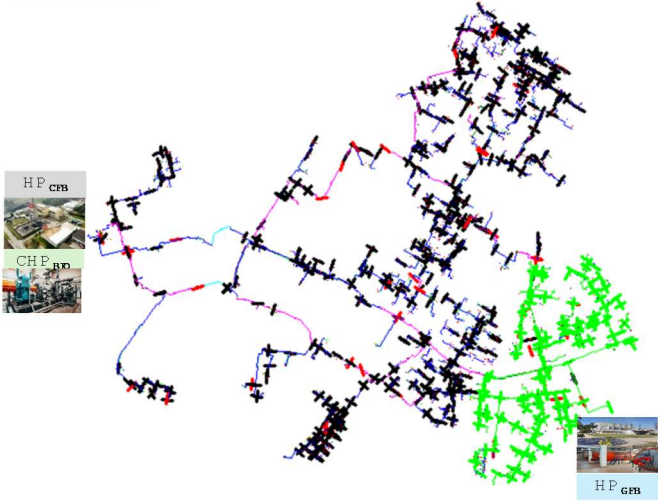




- **Fuel and Energy Mix:** Each case study provided a breakdown of heat production by source. This shared metric was fundamental for comparing the degree of decarbonization. Several of the systems are now predominantly biomass-fueled, while others still rely heavily on fossil fuels – the fuel mix metric quantified these differences. By tabulating fuel shares, the consortium could readily see how far along each network is on the path to decarbonization. The metric also helps in scenario modelling – for example, partners can use the current fuel split as a baseline and then project future scenarios (in Deliverable D2.3) where renewable fractions increase. Tracking the fuel mix over time (as some reports did historically) was additionally useful to note trends.
- **Specific Emissions (CO<sub>2</sub> per kWh) and Total Emissions:** To evaluate environmental performance, a carbon intensity metric (grams CO<sub>2</sub> per kWh heat delivered) was used, along with total annual CO<sub>2</sub> emissions. Given different accounting approaches (especially regarding biomass CO<sub>2</sub> and industrial waste heat), the consortium took care to document assumptions behind emission figures. The project captured these values to compare the notional carbon footprint of each network. Even where official specific emissions were low, partners qualitatively discussed the implications. Using a common metric of g CO<sub>2</sub>/kWh (or tonnes CO<sub>2</sub> per year) allowed the team to identify which systems have the greatest climate impact and require the most urgent action to decarbonize. It also provided a baseline for measuring improvements in future deliverables.
- **Network Configuration and Density:** Although more qualitative, each report included descriptions of network layout (looped vs. branched, number of substations, urban vs. rural setting) and a metric for customer density (e.g. MW per km of network). This helped contextualize the other performance metrics. A sprawling rural network with low density might inherently have higher losses per km, for example, than a compact urban system. By documenting figures like number of end-users, heat demand per kilometre, and major network branches, the consortium could relate technical performance to structural factors. Such comparisons via shared metrics ensured a contextualized evaluation, where differences in efficiency or emissions could be understood in light of network size and design.

Using these shared metrics across all six case studies enabled a systematic cross-site analysis. The consortium was able to create summary tables and charts to directly compare, for example, loss percentages, supply temperatures, or biomass shares side by side. This common analytical framework not only highlights the relative strengths and weaknesses of each district heating system, but also lays the groundwork for formulating collective strategies. The shared metrics approach is therefore a cornerstone of the project's cross-partner analysis, providing clarity and consistency in evaluating progress toward decarbonizing district heating.

### 3 Assessment analyses

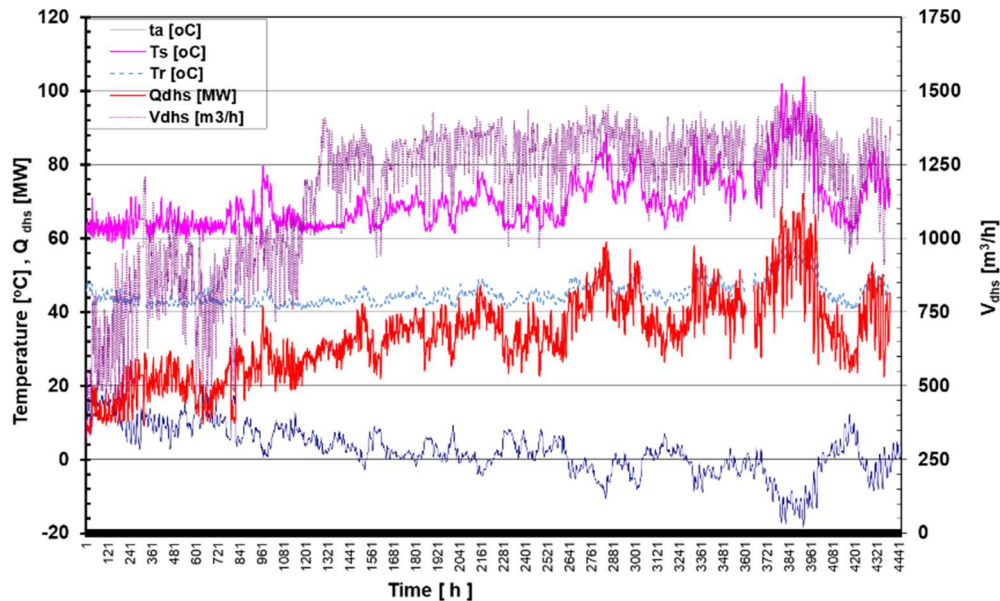
#### 3.1 IMP PAN: Łomza – Poland

##### 3.1.1 The district heating system in ŁOMZA operated by “MPEC Łomża”

INITIAL STATE, Year 2017	STATE up to Year 2022
 <ul style="list-style-type: none"> <li>• <math>T_s / T_r = 121/65 \text{ }^\circ\text{C}</math>,</li> <li>• 100 % coal, WR-25 boilers,</li> <li>• DHS transmission losses 16%,</li> <li>• 839 district heating substations,</li> <li>• 155 km network length,</li> <li>• Heat production: 100% from coal</li> </ul> <p><b>STATE up to Year 2022</b></p> <ul style="list-style-type: none"> <li>• Heat production: 100% from coal</li> <li>• <math>T_s / T_r = 109.8/61.8\text{ }^\circ\text{C}</math>, 2018</li> <li>• <math>T_s / T_r = 96.8/63.8\text{ }^\circ\text{C}</math>, 2022</li> <li>• DHS transmission losses below 11%</li> <li>• 860 district heating substations</li> <li>• 160 km network length</li> <li>• Heat production: Coal 10.6%, Biomass 52.0%, Gas* 36.4%</li> </ul> <p>*(in XII 2021 the Gas Heat Plant was taken out of service due high gas price md)</p>	 <p>DHS in ŁOM ŹA</p>  <p><b>Figure 3.1: DHS in Łomża.</b></p>
<p><b>STATE up to Year 2024</b></p> <div style="display: flex; flex-direction: column;"> <div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;">  <p>1. BIOMAS 12.5 MW water boiler          - Type - VHB-12.5          - Rated output - 12.5MW          - Water volume - 52.10 m<sup>3</sup>          - Operating pressure - 11 bar</p> </div> <div style="border: 1px solid black; padding: 5px;">  <p>2. Combustion furnace for burning biomass fuel          - Type - JSC          - Fuel power - 14 MW          - Flue gas temperature - 950-1050 °C          - Thermal load of the grate ≤ 450 kW/m<sup>2</sup></p> </div> </div>	<div style="display: flex; flex-direction: column;"> <div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;">  <p>3. Condensing economiser (heat recovery from flue gas condensation)          - Type - CEB 3000          - Rated output - 2.4 MW</p> </div> <div style="border: 1px solid black; padding: 5px;">  <p>4. A new COGENERATION UNIT with a thermal output of 14.0 MW and an electrical output of 2.8 MWE is commissioned in 2022.</p> </div> </div> <p><b>2024</b></p> <p>164 km network length</p> <p>915 substations in the DHS</p>

- Heat production :  
Coal 27.5%, Biomass 72.5%, Gas\* 0.0%  
\*(the Gas Heat Plant is taken out of service due to till high gas price md)

Figure 3.2 presents measured parameters of the whole DH grid during whole heating season 2017/2018 after implementation of first stage changes.



**Figure 3.2: Measured (hourly averaged) data during heating season 2017/2018: supply ( $T_s$ ) and return ( $T_r$ ) temperatures, ambient air temperature ( $t_a$ ), volumetric flow rate ( $V_{dhs}$  – volume velocity) and total thermal power delivered to DHS ( $Q_{dhs}$ ); the arrow shows the moment of first-stage changes implementation.**

The supply temperature ( $T_s$ ) during 30% of heating season oscillated around 60 – 70 °C and only 10% of the season exceeded 80 °C, mirroring temperature drop below 0 °C. Very similar behaviour can be traced in heat demand curve -  $Q_{dhs}$ . The return temperature was more stable – kept mostly around 40-50 °C, and generally provided more than 20 °C temperature drop which proves efficient work of the DHS. A high temperature difference between supply and return pipes is desired to limit the network flow rate. This reduces pumping power and increases the network capacity.

The municipal District Heating System (DHS) in Łomża, like most similar systems in Poland was designed in the 1970-ties taking into account the assumed planned rapid development of the city. This unrealised plan as well as thermo-modernization of most buildings performed during last 30 years, resulted in large oversizing of the whole system. In 2017, the grid 160 km in length and with 860 substations provided heat from a 100% coal-fuelled boiler. The nominal heat demand from the heat plant was 98.52 MW<sub>th</sub> but after verification it was corrected to 73.71 MW<sub>th</sub>. The nominal supply and return temperatures:  $T_s/T_r = 121$  °C / 65 °C, which led to actual heat losses of DH grid: - 12.5%.

The implemented methodology in the context of Łomża DHS decarbonisation, involved a 3-stage process:

- Assessment of the entire grid and regulation of heat substation which works under significantly changed conditions after thermomodernisation,
- Modelling and modernization of the whole DHS,
- Decarbonisation of DHS.

So, the first action undertaken was related to DHS assessment and adaption to real heat demand.

The traditional two-pipe central heating systems in Łomża (Figure 3.2) consists:

- 3 heat sources located on the west and east sides of the Łomża City, CHPBIO - cogeneration plant fuelled by biomass and two HPCFB,
- pipes length 160 km, with diameters varied from 20 mm to 700 mm,
- 860 heat substations.

According to the analyses carried out for the Łomża DHS, the area of the heat exchangers used in heating substation in relation to the actual heat needs of individual buildings is on average over 2 times overestimated (in some substations even more than 7 times). Also, the technical condition of heat exchangers was not good (excessive degree of contamination). Based on the surveys, measurements and analyses carried out, it was concluded that 242 heat substations in the district heating system of the city are characterised by a low degree of heat transfer (low cooling degree of network water). An average temperature of the return network water from substations (with low network water temperature drops) in the heating season was about 65.4 °C with an average supply temperature  $T_s = 101.9$  °C and an average outdoor air temperature  $t_{ext} = -11.3$  °C. The mass flow rate from substations with low temperature drops was 376 t/h. Under the same conditions, the average return temperature of network water from substations with higher temperature drops was ~49.1 °C. The network water mass flow rate from similar substations but with higher temperature drops was 530.6 t/h. Also, during the summer, more than 50% of thermal substations (285 substations out of 551) were characterised by low cooling of network water.

In contrast, an implementation in renovated building of a proper thermal-hydraulic regulation of central heating installation and substations as well as a decrease of supply temperature can result in lower heat losses and cost of the supplied heat (10-20%) and real decrease of heat consumption in the buildings (~30%).

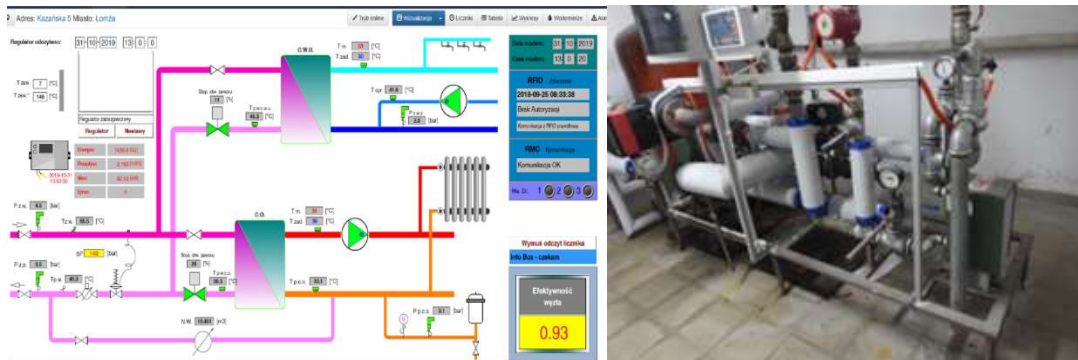
Moreover, during DHS assessment it was found that many substations have been designed with incorrect design assumptions concerning, among other things:

- calculated heat demand (usually too high),
- supply and return temperature of the network water (too high),
- available pressure in heat substations.

Taking into account the results of DHS assessment, in order to increase its actual energy efficiency, an operational action plan was established, which focussed on issues related to oversized DH systems, including heat exchangers in the DHS and the hydraulic capacity of the existing district heating network. As a result, this can facilitate the decrease of supply temperature (even below 98 °C - the issue will be discussed later) and heat losses in the whole grid. On the other hand, oversized heat exchangers operate in the buildings at too low flow rates (several cm/s) during the heating season - which in turn contributes to fast rate of fouling of the heat exchangers and an increase in the heat transfer resistance. It reduces their energy efficiency, increases the returning water temperature from substations and leads to decreased efficiency of the entire heating system.

So, the first stage of the implemented new methodology focused on the required actions related to heat exchangers of chosen heat substations:

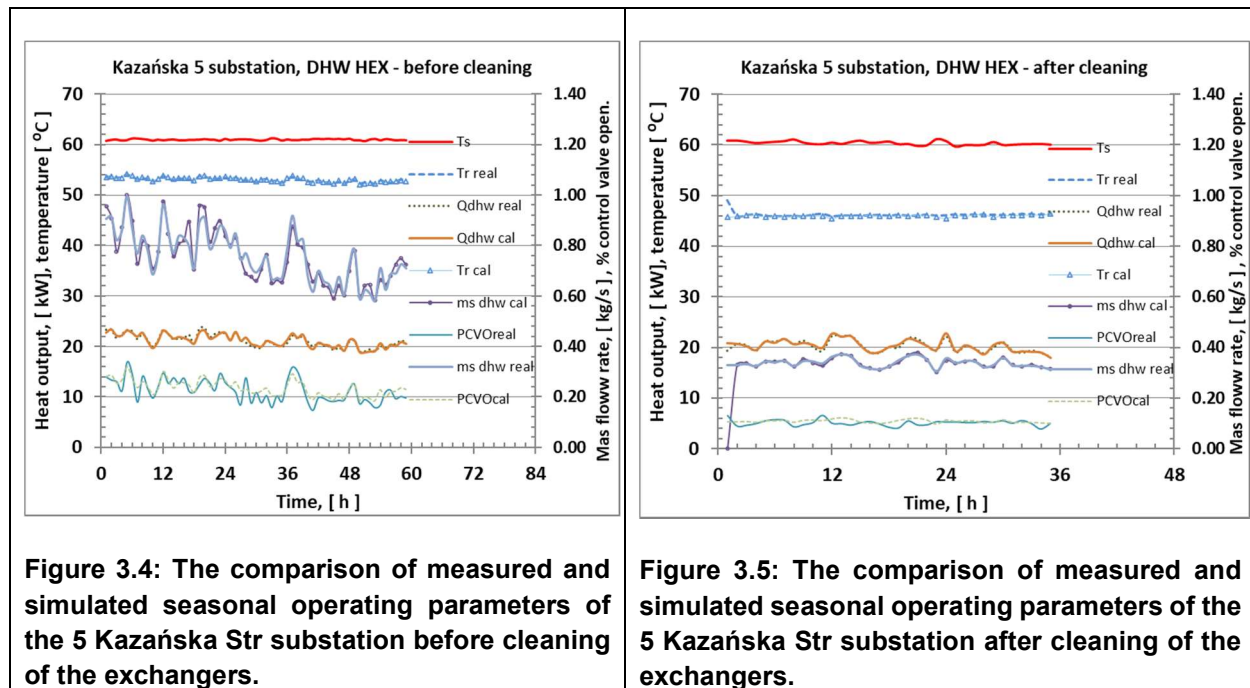
Chemical flushing of heat exchangers for CH and DHW – especially those where small difference  $\Delta T_s$  were registered. Preliminary results of DHW system operation after chemical flushing confirmed the correctness of developed methodology.



**Figure 3.3: The Kazańska 5 str substation layout.**

- After chemical flushing and redesigning of heat exchangers the "individually profiled" "New Control Tables" for the operation of heat substations during the next heating season should be developed; thermal and hydraulic characteristics should be calculated.

The works aim in the future to lower the so-called "heating curves" at customers which improves energy efficiency of building and whole urban DHS. This leads to a reduction of heat losses, fuel consumption and emissions as well as increase the potential RES application. The base for the reduction of heating curves is building thermomodernisation and related significant oversized radiators, heat exchangers, control valves, etc. However, important obstacle might be the consumer disinterestedness, so methods of consumer involvements in the process should be developed e.g. by proposing new heat tariffs promoting the lowering of the substations return temperature  $T_r$  and the definition of rules for its verification.



**Figure 3.4: The comparison of measured and simulated seasonal operating parameters of the 5 Kazańska Str substation before cleaning of the exchangers.**

**Figure 3.5: The comparison of measured and simulated seasonal operating parameters of the 5 Kazańska Str substation after cleaning of the exchangers.**

For example, detailed thermal-hydraulic analysis showed that the heat substation in the building at 5A *Żeromskiego St.* has been characterized by a very low heat transfer efficiency for a long time. During the measurements at low ambient temperature ( $-15.3\text{ °C} < t_{\text{amb}} < -8.0\text{ °C}$ ) and network water temperature (92.9

$^{\circ}\text{C} < T_{\text{sx}} < 108.6 \text{ }^{\circ}\text{C}$ ), the actual drop of the network water temperature was from 5.1 to 7.5 K. As a result, the required network water mass flow per 1 kW of supplied power is more than 7 times greater than in properly operating substation.

Performed adjustment and regulation of heat substations enable lowering of supply and return temperatures (as well as related temperature drop and heat losses); new heating curves for substations were determined. These actions enabled reduction of actual mass flow rate on network water by 55% and temperature drop (between supply and return temperatures) by 43.2%. Besides, the adjustment and cleaning of substations and providing new heating curves removes some sources of instability for DHS operation which enables its modelling and preparing further modernization and establishing heating curve for an entire DHS. The discrepancies between calculated and measured values of parameters does not exceed 4%.

The first stage implementation of proposed methodology in Łomża (including new adjusted heating curves for substation) resulted at this stage in a reduction of nominal supply temperature in DHS from 121  $^{\circ}\text{C}$  to 109,8  $^{\circ}\text{C}$ . It must be pointed here that this was possible due to heat grids as well as heat exchangers in buildings being oversized.

Besides, the implemented modernization resulted in 14% reduction of heat losses in the DH grid, when related to the mean heat losses registered for two previous heating seasons. Also, the hydraulic stability of the DH system was improved significantly during the whole heating season. For example, before the implementation (in 2015/2016 heating season) a volumetric flow rate in grid varied in the range 250 and 1322  $\text{m}^3/\text{h}$  (mean value being 953  $\text{m}^3/\text{h}$ ), i.e. it varied by a factor of more than 5 during the season (see Figure 3.4). After the first stage implementation (in season 2017/2018) total volumetric flow rate in the heat grid varied between 912  $\text{m}^3/\text{h}$  and 1501  $\text{m}^3/\text{h}$  (mean value 1229  $\text{m}^3/\text{h}$ ), i.e. (total flux changes only 64% during whole season) – see  $V_{\text{dhs}}$  after 1300 h in Figure 3.5. This makes DHS control and operation easier as well as more reliable under lower pressure and leads to increased system efficiency as well as decreased losses. The cold and warm water flux-mixing-systems work under much better seasonal conditions; a stable grid-water flux through boilers make it easier to keep lower supply temperature during the heating season and fulfil requirement of the new individually profiled heating curves. In the whole 2017/2018 heating season deviation of supply temperatures from those required by new heating curves was halved.

### 3.1.2 Decarbonisation of Łomża DH system

Taking into account the European policy and accepted ETS system, the strategic goal under current technical and economic situation in DHS Łomża was to reduce as quickly as possible the share of coal in the primary energy balance. Initially the most straightforward solution (basing on performed assessment) was to optimize the work regime of the biomass boiler located in Municipality Heat Plant and the new Gas Fired Boiler located in City Hospital.

For the purposes of the project, a new analytical model of the entire district heating system was developed, with detailed descriptions of the operating conditions of radiators, central heating installations, heat exchangers and entire single- and multi-functional heating substations in parallel and series-parallel systems.

The model diagram and description of the basic parameters are presented in the figure below.

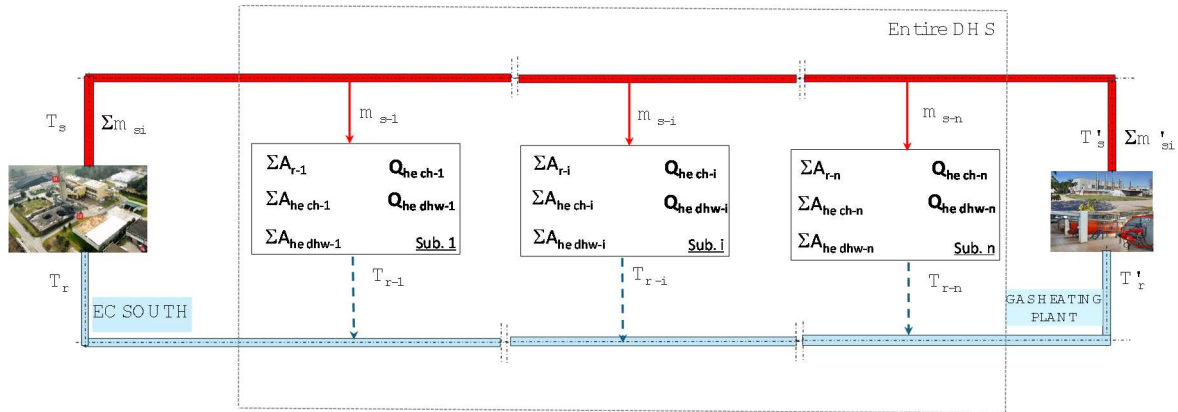


Fig. 3.5.a Equivalent diagram of the individual substations of the considered district heating system in Lomža;  $T_s$  ( $T_r$ ) - primary supply and return water temperature for DHS [ $^{\circ}\text{C}$ ];  $m_{s-1}$ ,  $m_{s-i}$ ,  $m_{s-n}$  - primary water mass flow rate for the 1-st, i-th and n-th substation, [kg/s];  $T_{r-1}$ ,  $T_{r-i}$ ,  $T_{r-n}$  - primary water return temperature from the 1-st, i-th and n-th substation [ $^{\circ}\text{C}$ ];  $Q_{he ch-1}$ ,  $Q_{he ch-i}$ ,  $Q_{he ch-n}$  - central heating heat demand for the 1-st, i-th and n-th substation [kW];  $Q_{he dhw-1}$ ,  $Q_{he dhw-i}$ ,  $Q_{he dhw-n}$  - dhw heat demand for the 1-st, i-th and n-th substation [kW];  $\Sigma A_{r-1}$ ,  $\Sigma A_{r-i}$ ,  $\Sigma A_{r-n}$  - total central heating, radiators surface in the 1-st, i-th and n-th substation [ $\text{m}^2$ ];  $\Sigma A_{he ch-1}$ ,  $\Sigma A_{he ch-i}$ ,  $\Sigma A_{he ch-n}$  - total central heating, exchangers surface in the 1-st, i-th and n-th substation [ $\text{m}^2$ ];  $\Sigma A_{he dhw-1}$ ,  $\Sigma A_{he dhw-i}$ ,  $\Sigma A_{he dhw-n}$  - total dhw exchangers surface in the 1-st, i-th and n-th substation [ $\text{m}^2$ ].

The actual layout of an urban DH system is represented by equivalent diagram (Fig. 3.5.a). The above diagram (Fig. 3.5.a) of a DH system has been aggregated to the final form shown in Fig. 3.5.b.

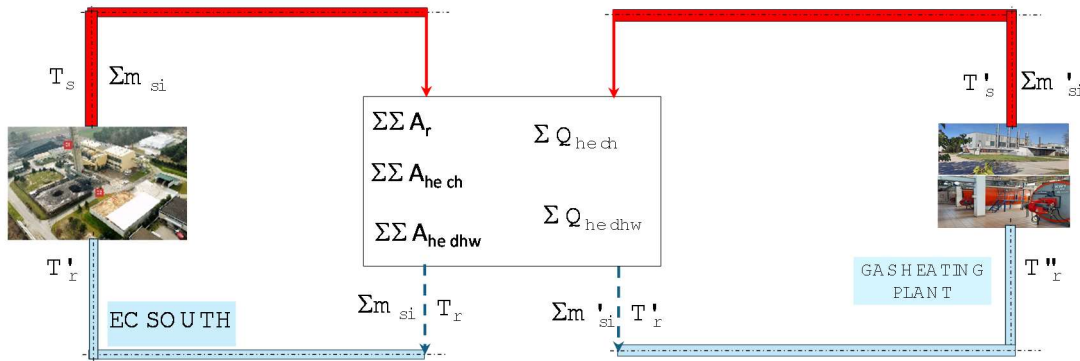


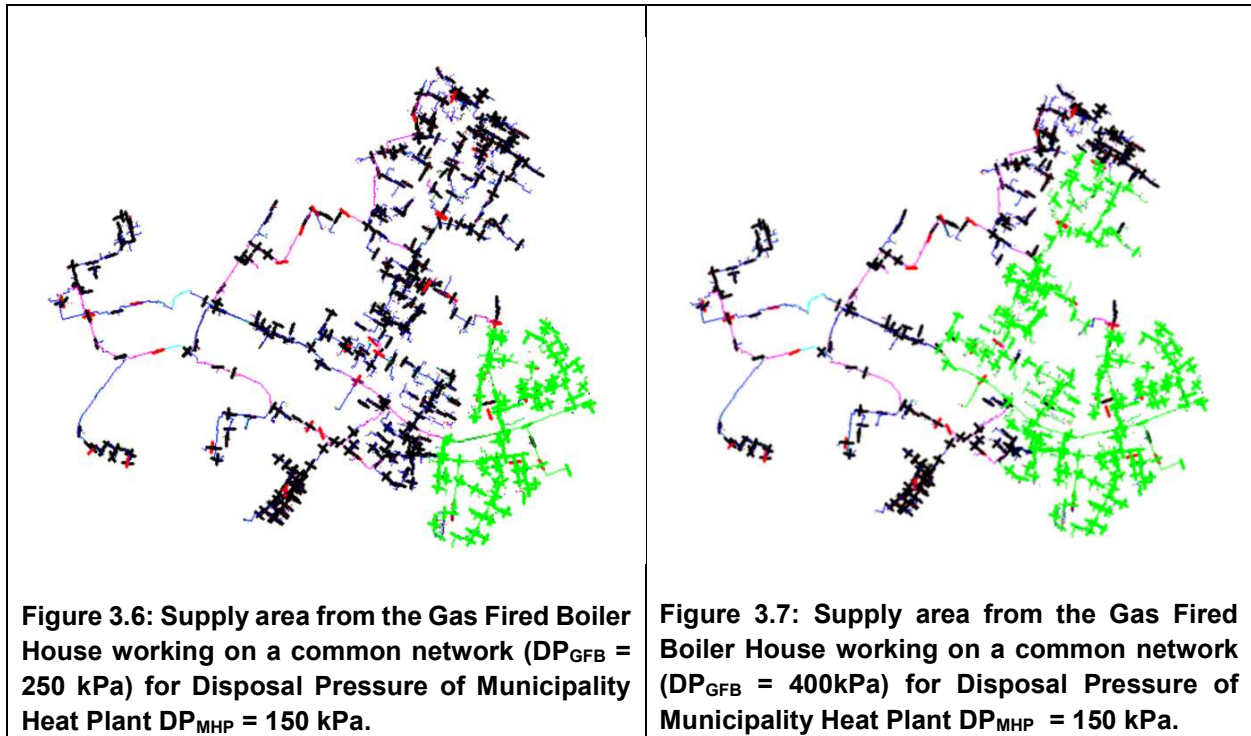
Fig. 3.5.b The final form of the aggregated, equivalent diagram of the entire district heating system;  $T_s$ ,  $T_r$  - primary supply and return water temperature for DHS [ $^{\circ}\text{C}$ ];  $\Sigma m_{si}$  - primary water mass flow rate for the entire substation [kg/s];  $\Sigma Q_{he ch}$  - total central heating heat demand for all substation [kW];  $\Sigma Q_{he dhw}$  - total domestic hot water heat demand for all substation [kW];  $\Sigma\Sigma A_r$  - total central heating, radiators surface in the ALL substation [ $\text{m}^2$ ];  $\Sigma\Sigma A_{he ch}$  - total central heating, exchangers surface in the all substation [ $\text{m}^2$ ];  $\Sigma\Sigma A_{he dhw}$  - total dhw exchangers surface in the all substation [ $\text{m}^2$ ].

Although the entire district heating system has been "aggregated" into one replacement substation, the complete data for each exchanger and set of radiators in all buildings, including their thermal and operational characteristics, are required. The proposed procedure allows the diagnosis problems and determination of "bottle necks" in the heat transfer process of the considered DHS. This enables a rational improvement in the actual energy efficiency of the entire DH system to be achieved.

The proposed "Aggregated District Heating System Model (ADHSmd)" provides the basis for detailed analysis of entire existing district heating systems in terms of improving their actual energy efficiency. The model was applied to monitor and improve DHS efficiency for the next stage i.e. decarbonisation.

Based on the developed Aggregated District Heating System "ADHSmd" model of the DHS in LOMZA, a series of simulations was carried out in order to optimize DHS operation in order to ensure a constant heat output supply from the Biomass Boilers, to reduce the heat supply from the Coal Fired Boilers as much as possible, and to supplement the required heat demand of the DHS by operating the Gas Fired Boiler flexibly.

This required the determination of the disposable pressure for the Gas Boiler Plant, at a level that would ensure the required heat demand in the DHS throughout the heating season. Figure 3.6 and Figure 3.7 show, as an example, the DHS areas supplied by Municipal Heat Plant with Disposal Pressures  $DP_{MHP} = 150$  kPa, and the Gas Fired Boiler for a disposal pressures  $DP_{GFB} = 250$  kPa and  $DP_{GFB} = 400$  kPa.

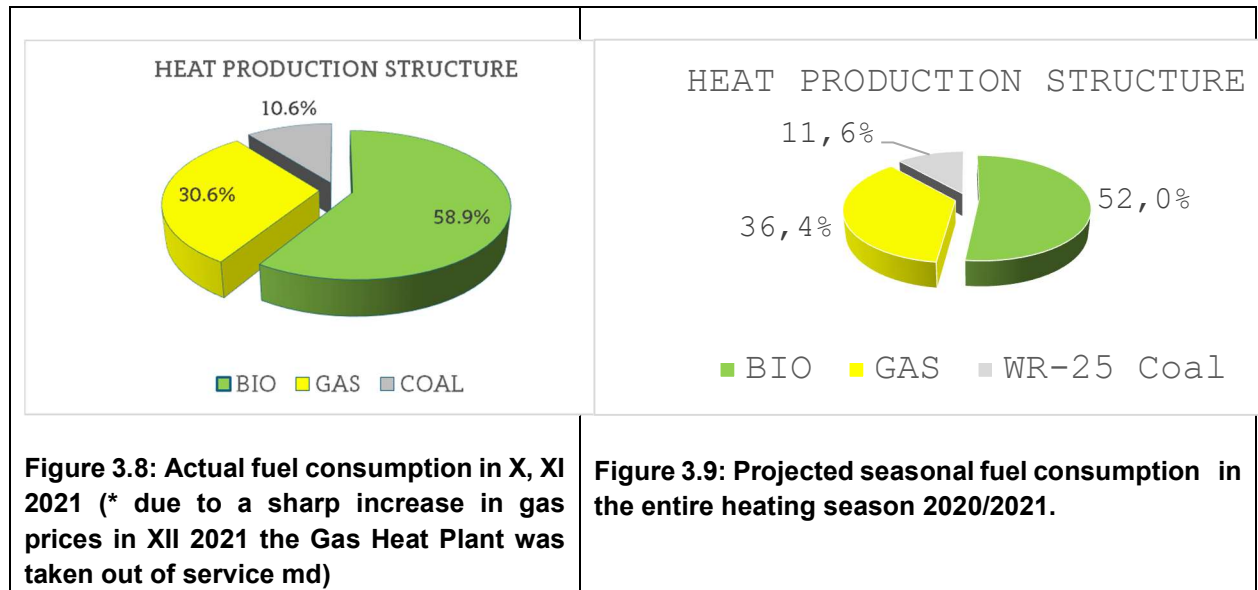


The carried-out simulations using "ADHSmd" model and following analyses showed that, in the heating season 2020/2021 under current conditions and appropriate operating parameters, it is technically possible to achieve:

- the share of the biomass boiler plant in the heat sales at the level of 52.0% (251 205 GJ/season),
- the share of the gas boiler plant in the heat sales at the level of 36.4% (175 935 GJ/season),
- limited share coal-fired boilers in the heat sales at the level of 11.6% (55 987 GJ/season),
- a total of 88.4% of heat sales from sources with higher energy efficiency and lower emissions (427 139 GJ/season).

Under such conditions, the biomass boiler will operate for 212 days throughout the heating season with a capacity ranging from 8.8 MW to 15.0 MW. The average capacity of the Boiler will be approximately 14.91 MW. The gas boiler plant will operate for 186 days with a capacity from 0.0-14.0 MW. The average thermal

power of the Gas Fired Boiler will be approximately 10.44 MW. The WR coal-fired boilers will operate for 84 days with the power from 0.0-36.9 MW. The average thermal power of WR boilers will be approximately 3.3 MW.



According to the measurements carried out in the months of X, XI 2020, the actual structure of fuel consumption in DHS: Coal 11.6%, Biomass 58.9%, Gas 30.6%.

According to simulation calculations in the months X, XI 2020, the predicted actual fuel consumption structure in DHS was as follows:

Coal 10.6%, Biomass 52.0%, Gas\* 36.4% (\*At the end of XI 2020, due to gas prices, a reduction in the operation of the gas-fired boiler plant was started).

### 3.1.3 Summary

It was found that in Poland (and probably other East European countries), due to oversized DH networks, it is possible to gradually transform existing district heating systems into grids with supply temperature below 100 °C. This is possible and takes advantage of oversized grid resulting from the huge work being done in respect of buildings thermal modernization. It is possible even taking into account that energy efficient refurbishment of all buildings in BSR countries is not feasible till 2050. Properly done grid modernization and implementation of "individually profiled rational quantitative and qualitative seasonal regulations" in existing DHS can result in a reduction of heat losses and costs of the supplied heat (10-20%) and real decrease of heat consumption in the buildings (~30%).

Besides, the grid hydraulic stability and working condition of mixing systems are improved significantly. This was already achieved due to the implementation of Stage I DHS modernization of the *"Program for rational quantitative and qualitative regulation along with the indication of rational measures to improve energy efficiency in the heating system of the city of Łomża"*. It was shown that it was possible to implement in the entire city of Łomża (the first in Poland) a DH system with a nominal supply temperature  $T_s$  below 98 °C.

The implementation of the methodology presented here, which resulted in the above presented results, required:

- chemical rinsing of heat exchangers for central heating and domestic hot water that were in poor technical condition. The preliminary analysis of the operation of domestic hot water system after chemical flushing of heat exchangers showed very positive effects.
- redesign of the existing heat substations, especially those with a low degree of cooling of the district water, adaptation of oversized heat nodes to the actual thermal needs of buildings, with the current operating conditions of the network - the actual temperature  $T_s/T_r$ , the available pressure, the required final temperature difference when selecting heat exchangers for central heating ( $T_{r, ch} - t_r$ ) and DHW ( $T_{r, dhw1} - t_{cw}$ ), where  $T_{r, dhw1}$  - DHW return temperature -  $t_{cw}$  cold water inlet temperature.
- locally adequate requirements and guidelines for designers for new heat substations so that they ensure the lowest possible temperature of water returning to the heating network and high efficiency of heat supply. The developed "Guidelines for designers" should also include the requirements for communication standards and the possibility of individual programming in the controller the actual thermal and hydraulic characteristics of the substations.

The subsystem supplied from the Gas Fired Boiler Plant, with the nominal thermal capacity of  $Q_n = 14.0\text{MW}$  and a share of more than 30% of seasonal heat sales, represent the first low carbon, high-efficiency, low-temperature DHS system in Poland, with a nominal primary supply water temperature  $T_s = 96.3\text{ °C}$  at the ambient air temperature  $t_{an} = -22.0\text{ °C}$ .

Conversion of the entire existing district heating systems into low-temperature systems (LTDH) also makes it possible to reduce heat transmission losses and pollutant emissions by 15% - 30%. In the district heating system of Łomża, heat transfer losses have been reduced by 31.2% (from 16.0% to below 11.0%).

"MPEC Łomża" may also be the first district heating company in Poland (and probably EU), where a system will be implemented and operated with an autonomous, individual energy efficiency assessment at the substations level and with a "Master System" for ongoing, follow-up optimization of the actual energy efficiency of the entire heating system during the heating season, supporting the "Network Dispatcher" in making rational "Operating Decisions". It should be stressed that all implemented activities were supported and enabled by the developed and fully verified thermo-hydraulic model of the existing DH system in the city, which constitutes a good basis for planning further modernisation activities. It was found that the difference between the calculated and measured:

- thermal power values ranged between -3.5% to +2.1%, on average -0.3%;
- network-water mass-stream values was from -1.9% to +3.0%, on average +0.2%;

temperature values of the network return water were from -0.2% to +1.4%, on average +0.4%.

### 3.2 OPEC: Wejherowo – Poland

The city of Wejherowo is supplied in 50 % from the heating system with a central heat plant and gas cogeneration engine. The modernization of the heating plants was made with equity capital and financial support obtained from GEF, EcoFund and the World Bank.



**Figure 3.10: Power plant in Wejherowo.**

### Location

Wejherowo is a city in Gdańsk Pomerania, northern Poland, with 46 446 inhabitants (2022).



**Figure 3.11: Location of Wejherowo.**

### General Information

The heat and power plant in Wejherowo - 2 Heat sources:

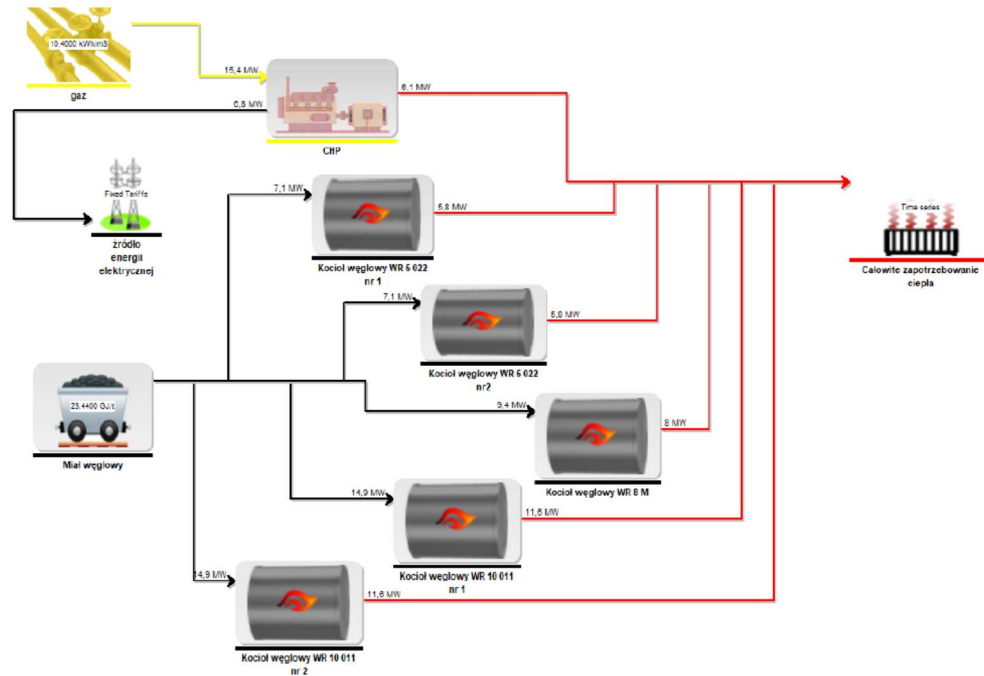
CHP Gas engine and HP Coal fired boilers

Net thermal power 48 MW<sub>th</sub>

Thermal power „Nanice” 42 MW<sub>th</sub>

Thermal power cogeneration .,0 MW<sub>th</sub>

Electricity power cogeneration 6.8 MW<sub>el</sub>



Rysunek 4 Uproszczony schemat systemu ciepłowniczego Wejherowa

Figure 3.12: Simplified diagram of the Wejherowo heating system.



Figure 3.13: Gas cogeneration engine.

Rolls-Royce gas engine used in a cogeneration system to simultaneously produce electricity and heat (see Figure 3.13).

### 3.2.1 Technical Specifications of heating system in Wejherowo

The district heating network (see Figure 5) of the district heating supply company. District Heating Enterprise Ltd (OPEC Gdynia) covers a pipeline length of approximately 44 kilometres in Wejherowo.

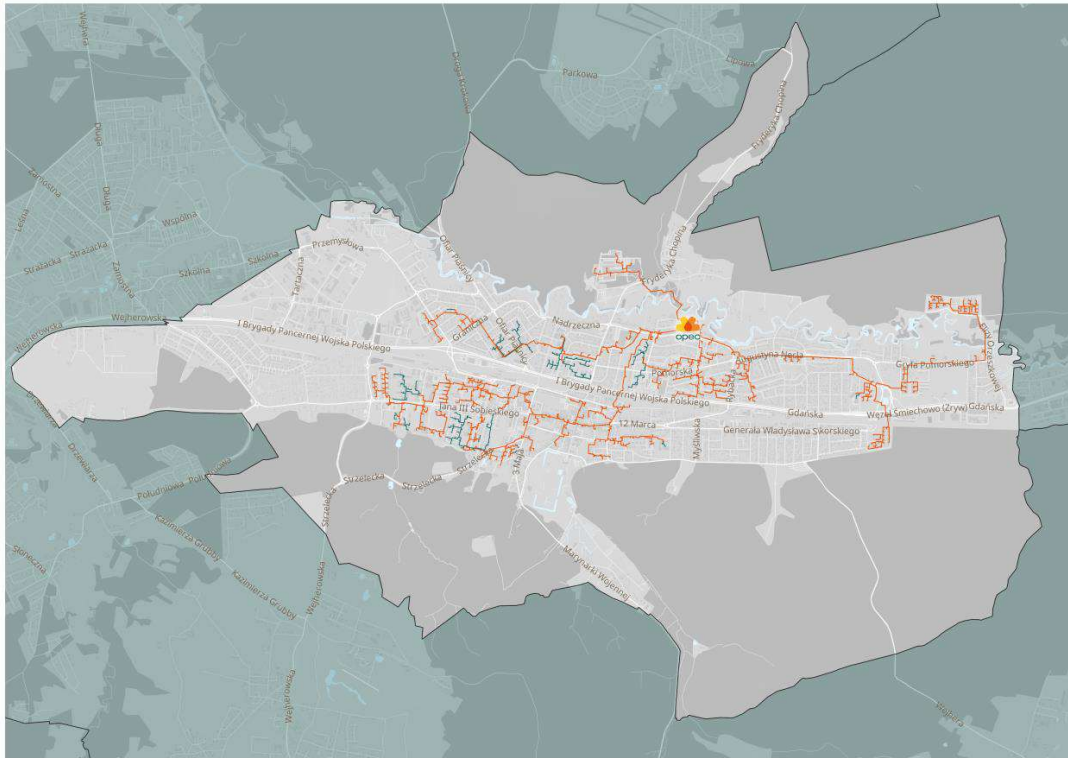


Figure 3.14: Heating system in Wejherowo.

### Heating Networks

Table 3.1 below shows the length of the high-parameter heating network divided into distribution main networks and connections.

Table 3.1: Types of high-parameter heating network.

Type of network	Main heating networks	Distribution heating networks	Connections
Network lengths [km]	25.0	10.0	9.0

Table 3.2 below shows the length of the heating network divided into construction technology.

**Table 3.2: Construction technology of heating network.**

Type of network	Pre-insulated networks	Traditional heating networks
Network lengths [km]	32.0	12.0

### Heating nodes

The total number of heating nodes in the heating system through which heat is supplied to facilities.

**Table 3.3: The total number of heating nodes.**

Type of node						In Total
Heat exchanger nodes						
d.h.	d.h.w.	d.h.+d.h.w.	d.h.+d.h.w.+t.h.	t.h.	d.h.w.+t.h.	
<b>pcs</b>						
<b>Individual heating stations</b>						
58	2	308	9	1	-	<b>378</b>
<b>Group heating nodes</b>						
1	1	7	-	-	-	<b>9</b>

d.h. – district heating; d.h.w. – domestic hot water; t.h. – technological heat

### Heating system operating parameters

- Supply and return temperature of the heating network : 108/55 °C
- Temperature in the installation : 72/54 °C
- Storage capacities : 1801 m<sup>3</sup>
- Pipe Losses : 15,4 %
- All system with heat sources is in the monitoring
- Pressure Level : 8 bar

### Estimated heat losses



Figure 3.15: Estimated heat losses during transmission (summer – green, winter – blue).

### 3.2.2 Environment and biodiversity

In our company, we care about the environment and biodiversity. That's way we take action to support the local ecosystem. Since 2018, we have been maintaining 14 beehives, including 4 located at the heating plant in Wejherowo. In 2024, our bees produced nearly 416 kg of honey. What's more, in May 2024, a kestrel nesting box has been installed on the chimney of the Wejherowo heating plant. This falcon species is protected in many countries as it may be vulnerable due to environmental changes. The nest is continuously monitored, and last year, the first chicks hatched there.



**Figure 3.16: An artificial nest for kestrel falcons in the Wejherowo heating plant.**



**Figure 3.17: An apiary in the area of the Wejherowo heating plant.**

### 3.2.3 Conclusions and Outlook

In June 2024, OPEC Gdynia adopted the "Plan for Achieving Climate Neutrality by 2050 for the Wejherowo District Heating System." The decarbonization plan for the Wejherowo CHP plant assumes the construction of new heat generating units, decommissioning existing coal-fired boilers and replacing them with low-emission technologies or renewable energy sources, including: a solar farm, a heat accumulator, a biomass boiler, adaptation of the WR-8 boiler to burn wood pellets, gas-oil boilers, an electrode boiler, and a heat recovery system from the exhaust gases of the cogeneration unit (see Figure 3.18).



**Figure 3.18: Visualization of the Nanice energy plant area after the investment.**

### 3.3 BEOF: Bornholm – Denmark

This report presents an overview of the district heating (DH) infrastructure on Bornholm, Denmark, as part of the DecarbonDHS project (Deliverable D2.1). The analysis focuses on the production capacity, system efficiency, carbon emissions, and strategic development of Bornholm's DH network operated by Bornholms Energi og Forsyning A/S (BEOF).

#### Key Findings:

- **System Overview:** The networks that BEOF operates serves approximately 6,700 customers across the island. It is organized into four main supply zones - Hasle, Nexø, Åkirkeby, and Østerlars. The network spans 260 km and delivers around 160 GWh of heat annually.
- **Energy Mix:** The system is nearly 100% biomass-based, with wood chips (77.2%), straw (22.4%), and minor contributions from wood pellets and oil. Approximately 86% of biomass is locally sourced, supporting regional sustainability.
- **Carbon Emissions:** Despite its renewable classification, biomass contributes to approximately 50,000 tons of CO<sub>2</sub> emissions annually. BEOF considers biomass a transitional fuel and is exploring alternatives. For the time being, biomass is considered CO<sub>2</sub> neutral.
- **Digitalization & Monitoring:** Advanced tools such as SCADA, TERMIS, Heat Intelligence, and EnergyPRO support real-time monitoring, hydraulic modeling, and strategic planning. Smart meters are installed across all connected buildings.
- **Maintenance & Reinvestment:** BEOF employs a proactive asset management strategy using Sertica for preventive maintenance and inventory planning. Reinvestment priorities focus on aging infrastructure in areas like Nexø and Klemensker.
- **Storage & Flexibility:** The system includes over 12,000 m<sup>3</sup> of thermal storage capacity (~900 MWh), aiding peak shaving and load balancing. However, challenges remain in older sections, including high return temperatures and limited redundancy.

- **Optimization Initiatives:** The Cooling Improvement Project aims to reduce return temperatures from 43–45°C to 35°C by 2028. A new tariff model incentivizes efficient heat return, and technical upgrades are underway in key production units.
- **Innovation & Future Strategy:** BEOF is piloting smart thermostats and demand response systems under the *Fleksibel Fjernvarme* initiative. Future plans include integrating surplus industrial heat and Power-to-X technologies aligned with offshore wind development.

### 3.3.1 Introduction

Bornholm, a Danish island located in the Baltic Sea with approximately 39,000 inhabitants, is a unique and semi-autonomous energy system in transition. The island is recognized as a strategic site for energy innovation within Denmark and across the EU, with a strong focus on renewable energy and local resource utilization. Its diversified economy includes tourism, agriculture, transport, and food production, and its energy sector is structured to reflect long-term sustainability goals.

The island's district heating is managed by Bornholms Varme A/S, a non-profit company owned by Bornholms Energi og Forsyning A/S (BEOF). BEOF was founded in 2016 following the consolidation of several local utility services and is fully owned by the Municipality of Bornholm. Today, BEOF operates electricity, water, wastewater, and heating services. The district heating system covers most populated areas on the island outside of Rønne and supplies heat to approximately 6,700 customers, including residential buildings, commercial units, and public institutions such as schools and swimming pools. The town of Rønne is served by a separate utility company, Rønne Vand & Varme A/S, which supplies district heating to approximately 5,300 customers in the town and surrounding area making a total of 12,000 district heating customers on the island.

The system is primarily based on locally sourced biomass fuels, mainly wood chips and straw, alongside biogas CHP and minor electric and oil-based peak-load units. In 2023, the total heat production amounted to approximately 160 GWh. Of this, 99.98% was covered by biomass-based fuels, with a mix consisting of approximately 77.2% wood chips, 22.4% straw, and 0.3% wood pellets. Around 86% of the biomass used is produced locally, reducing transport emissions and supporting regional resource cycles. While biomass is often classified as renewable in energy statistics, BEOF acknowledges its associated CO<sub>2</sub> emissions and considers it a transitional fuel.

### 3.3.2 Historical Development

The development of BEOF's district heating network began in the early 1980s, when the first systems were established in towns such as Nexø, Klemensker, and Lobbæk. These initial networks were typically oil-fired and constructed using conventional materials and techniques. They represented the first coordinated attempt to supply centralized heat to smaller communities outside Rønne.

During the 1990s and early 2000s, the island began transitioning toward biomass-based heating, driven by national energy policy and Bornholm's growing environmental ambitions. Local production plants were established in towns including Hasle, Østerlars, and Åkirkeby, creating a decentralized system structure where each town could supply its own demand. This shift reduced reliance on fossil fuels and allowed for the use of locally sourced wood chips and straw, supporting regional economic and environmental goals.

In 2009, Bornholm entered a new phase of development through a major expansion of the district heating network. New areas were connected via modern pre-insulated pipelines, and the technical standard of the system improved significantly. This second rollout enabled wider access to district heating across both urban and rural areas and laid the foundation for future digital upgrades.

A significant institutional milestone occurred in 2016 with the formation of Bornholms Energi & Forsyning A/S (BEOF). This municipally owned, non-profit utility brought together the island's electricity, water, wastewater, and heating services under a single organization. The merger allowed for coordinated investment planning, integrated infrastructure management, and streamlined customer support across the utility sectors.

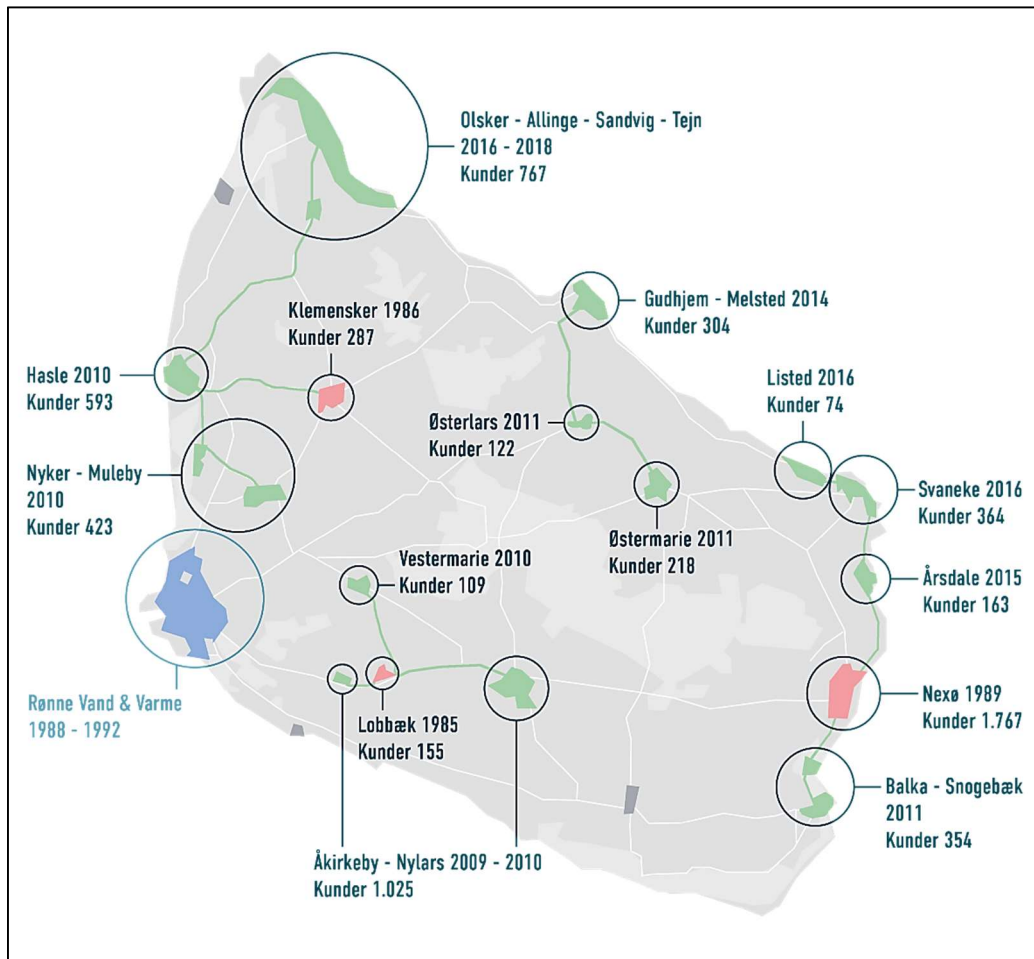
Since the 2020s, BEOF has continued to modernize the heating infrastructure by rolling out island-wide smart metering and introducing advanced digital tools for planning and operations. Rather than a static utility system, Bornholm's district heating infrastructure has evolved into a dynamic, data-driven network aligned with Denmark's and the EU's broader decarbonization objectives. The focus in recent years has been on operational efficiency, customer engagement, and long-term system flexibility, building on four decades of continuous technical and organizational development.

### 3.3.3 System overview

Bornholm's district heating network is organized around four decentralized supply zones: Hasle, Nexø, Åkirkeby and Østerlars. Each with one or more production plants and transmission connections to nearby towns and villages. Smaller nodes such as Klemensker, Lobbæk, Gudhjem, Svaneke, and Årsdale are integrated as satellite areas through secondary infrastructure.

Each main supply zone incorporates transmission connections to adjacent branches and may include local energy storage capacity. The system serves both compact urban centres and more scattered rural communities, resulting in a geographically diverse and hydraulically segmented network. In addition to its technical layout, the system is defined by broad customer integration and smart digital features. Today, more than 80% of all buildings on Bornholm are connected to the district heating network. All connected properties are equipped with smart meters for water, heat, and electricity, enabling precise monitoring and data-driven optimization. Furthermore, every customer has a domestic hot water tank of at least 100 litres, and newer installations are equipped with Danfoss ECL intelligent controllers, which regulate indoor temperatures dynamically in response to outdoor conditions.

The total pipeline network covers approximately 260 km, comprising 163.5 km of main pipelines and 101.4 km of service connections. Transmission pipelines alone span 57.1 km. The network was rolled out in two phases: the first in the 1980s included areas such as Nexø and Klemensker; the second began in 2009 and introduced broader coverage and newer technologies. While some older sections have less than 10 years of expected technical lifetime, more recent installations are projected to remain in service for another 30 to 37 years with proper maintenance.



**Figure 3.19: Overview map of the district heating network on Bornholm, 23 August 2024.**

Figure 3.19 shows the distribution of district heating and customers across Bornholm. Green areas indicate newer distribution networks, while red areas represent older ones. The blue area indicates a region where another provider supplies district heating. The names of the towns and the year of network establishment are shown at the top of each area. The word 'kunder' means 'customers'.

The system has an installed heat capacity of approximately 81.1 MW and delivers around 160 GWh of heat per year. This corresponds to a power density of 0.62 GWh per kilometre of pipeline, a figure that reflects the spatial structure of heat demand and supports assessment of operational efficiency. This density is typical for semi-rural systems and underscores the balance required to serve both densely built areas and dispersed villages across a larger geographic area.

### 3.3.4 Digital control and monitoring

The network is digitally monitored and managed using several advanced systems. Embedded within the insulation of transmission pipelines is the LOGSTOR Detect system, which continuously monitors for leakage and moisture using copper wire sensors and resistance analysis. This allows for early warning and targeted repairs, which prolongs pipe lifetime and reduces heat losses.

Planning and operational tools include:

- **TERMIS** for hydraulic modeling and pressure simulations
- **Heat Intelligence** for real-time data monitoring and demand analysis
- **EnergyPRO** for strategic planning and fuel-mix modeling

- **SCADA** for centralized operational control
- **Sertica**, introduced in 2023, for maintenance management and inventory planning

A formal asset management strategy defines system reinvestment needs and evaluates risk across asset classes based on technical lifetime and wear.

### **Maintenance and reinvestment strategy**

BEOF maintains a structured and proactive approach to asset management across the district heating network. Preventive maintenance and condition monitoring are supported by digital tools such as Sertica, which was fully implemented in 2023. Sertica enables centralized tracking of asset history, scheduling of preventive maintenance tasks, and management of spare parts inventory. These capabilities allow for early fault detection, reduced unplanned downtime, and improved operational continuity.

In addition, performance data from TERMIS and SCADA is used to identify anomalies in pressure, flow, and temperature, helping to locate underperforming assets or pipeline segments. This data-driven insight feeds into BEOF's annual reinvestment planning, which defines technical priorities and allocates resources based on component age, wear patterns, and system criticality.

Special attention is given to aging sections of the network, particularly in areas such as Klemensker and Nexø, where parts of the infrastructure are approaching the end of their technical service life. Planned reinvestments include pipe insulation upgrades, valve replacements, and modernization of control equipment. In zones with limited redundancy or high peak-load sensitivity, reinforcement projects are prioritized to strengthen supply security and system robustness.

While the overall network is in good operational condition, BEOF's reinvestment strategy is designed to ensure long-term resilience, reduce heat losses, and maintain alignment with the island's decarbonization goals.

#### **3.3.5 Storage and flexibility**

Thermal energy storage is installed in all main supply areas and supports peak shaving, emergency backup, and load balancing. The total storage capacity exceeds 12,000 m<sup>3</sup>, equivalent to approximately 900 MWh, enabling stable operations across variable seasonal loads. Load dispatching and return temperature regulation are coordinated via SCADA and local temperature nodes.

Despite these technological strengths, certain limitations persist, particularly in older sections. These include:

- Elevated return temperatures (43–45 °C), which reduce thermal efficiency
- Under-dimensioned pipelines in some branches, restricting flow and storage discharge
- Aging segments (notably in Nexø and Klemensker), with higher risk of leakage
- Limited fuel-switching flexibility in mono-fuel boiler houses
- Insufficient redundancy in some peripheral zones

### 3.3.6 Optimization initiatives

To address identified inefficiencies in the network, BEOF has launched the Cooling Improvement Project, which aims to reduce average return temperatures from their current levels of 43–45 °C to a target of 35 °C by 2028. A specialized “cooling team” works directly with customers to improve the hydraulic performance of internal heating systems. In 2023 alone, the team conducted nearly 800 on-site visits, focusing on balancing, technical adjustments, and consumer guidance.

As part of the broader effort to support this transition, a new return temperature tariff model was introduced in 2025. Under this system, customers will be categorized into bonus, neutral, or penalty groups depending on how efficiently they return heat to the system. This approach is intended to incentivize better usage patterns and encourage technical upgrades at the consumer level.

In parallel, BEOF has implemented a series of technical upgrades to production infrastructure. In Hasle, the wood chip boiler was retrofitted with an air-mixing system to reduce combustion temperature fluctuations and extend the durability of grate components. A similar combustion optimization project is planned for the straw-fired boiler in Nexø in 2025, which is one of the island’s key base-load production units. Additionally, shunt valves have been installed in Østerlars and Nexø to allow more precise temperature control in long-distance transmission branches, particularly toward Gudhjem and Årsdale, without destabilizing the core supply in the originating zones.

### 3.3.7 Innovation and future strategy

BEOF is actively exploring technological innovation and long-term decarbonization strategies to enhance the performance and adaptability of the district heating system. One example is *Fleksibel Fjernvarme*, a pilot program integrating smart thermostats and real-time demand response tools. Test deployments of Neogrid Preheat systems are active in Listed, Svaneke, and Årsdale, enabling adaptive preheating based on ambient temperature and consumption patterns.

Although the system is nearly 100% biomass-based today, BEOF recognizes its carbon impact—estimated at around 2,900 tons of CO<sub>2</sub> per year—and considers biomass a transition fuel. Future strategies include exploring surplus heat integration from industrial sources and linking to Power-to-X infrastructure aligned with Bornholm’s offshore wind potential.

As a municipally owned non-profit utility, BEOF reinvests all surpluses into infrastructure, digital systems, and decarbonization. Bornholm’s district heating network not only supports local resilience, but also stands as a scalable model for rural and island communities aiming to build intelligent, low-carbon thermal energy systems.

**Table 3.4: System parameters of BEOF DH on Bornholm.**

Parameter	Value	Comment
Location	55.13° N, 14.91° E	Bornholm
Country	Denmark	
Length of pipelines	260 km	163.5 km mains + 101.4 service
Installed load	39 MW (81.1 MW)	Baseload (incl. peak + reserve)
No. of costumers	6,722	
Power density	0.62 GWh/km	Heat production per km of pipe

Flow temperature	>80 °C flow	
Return temperature	43-45 °C	Target: 35 °C by 2028
Pressure level		
Pipe losses	~26%	Produced minus sold energy
Pipe diameters	170/450 mm	Twin pipes, various sizes
Pipe insulation	Pre-insulated steel pipes	LOGSTOR leakage monitoring
Grid topology	Decentralized, zone-based mixed urban/rural structure	
Storage capacity (total)	>12,000 m <sup>3</sup> ≈ ~900 MWh	
Carbon emissions (CO <sub>2</sub> )	2,900 tons CO <sub>2</sub> /year	Straw and wood are considered CO <sub>2</sub> neutral. CH <sub>4</sub> and N <sub>2</sub> O is however included. Primary emissions from transportation (scope 3)
Digitalization & control	TERMIS, SCADA, Heat Intelligence, EnergyPRO	

### 3.3.8 Conclusions and outlook

Bornholm's district heating system, operated by BEOF, stands as a resilient and digitally advanced infrastructure. With nearly 100% of heat production based on locally sourced biomass, the system supports regional sustainability but still contributes approximately 50,000 tons of CO<sub>2</sub> annually—highlighting the need for continued decarbonization.

Ongoing optimization efforts, including the Cooling Improvement Project and smart metering, are improving system efficiency and customer engagement. Strategic reinvestments target aging infrastructure, while pilot programs like *Fleksibel Fjernvarme* explore future-ready technologies.

Looking ahead, BEOF aims to reduce carbon emissions by integrating surplus industrial heat, enhancing flexibility, and exploring Power-to-X solutions. Bornholm's DH network offers a scalable model for rural and island communities seeking intelligent, low-carbon energy systems.

## 3.4 KDH/KM: Kretinga – Lithuania

Kretinga District heating company UAB „Kretingos šilumos tinklai“ started its activity on 28 April 1981, when the Directorate of Joint Boiler-houses and Heat Networks of Kretinga District was established. After several status changes from 8 December 2003 current company UAB „Kretingos šilumos tinklai“ started.

Currently, Kretinga DH company operates 20,209 km of outdoor heating pipelines in Kretinga town and district. Thermal energy for heating and hot water is supplied to over 250 buildings or 3,567 heat consumers.

The company has 28 boiler houses with a wide variety of operating installations, including over 50 different water heating boilers, auxiliary equipment for optimising and controlling operating modes, air cleaning equipment, automation equipment, and various other auxiliary facilities. All these were constantly updated and adapted, as well as improving technical parameters in response to modern development trends, and

more economic fuels of the time. The company was one of the first in Lithuania, and probably the first in the western part of the country, to introduce technologies that allowed the introduction and combustion of biomass fuel, i.e. the residual product of wood processing, in a partially automated way, as early as 1998. The company started using biomass pellets in small boiler houses in 2003 and 2004. Kretinga DH company was one of the first to reach the threshold of almost 90% biomass fuels in the total fuel balance.

The switch from natural gas to biomass as the main fuel has also been accompanied by the reduction of combustion emissions, i.e. the installation of multi-cyclone air purifiers, which capture 87-90% of the solid particles in the flue gas. In 2011 the company installed a new generation industrial condensing economiser, which had several purposes: improving the efficiency of biomass boilers operation, as well as trapping around 63% of the solid particles in the flue gases after the multi-cyclone. This led to the installation of a new modern flue gas stack in 2019 which met the new technical requirements

Each year, the company invests in upgrading installations in boiler houses and heat supply networks to ensure a reliable and cost-effective supply of thermal energy to consumers. This saves fuel and reduces losses in the network.

In 2018, the company implemented the project "Reconstruction of the main heat pipelines of the boiler house No.2 in Kretinga town". The value of this project was EUR 537.5 thousand, 50% of which was supported by the European Union Structural Funds. The project resulted in the reconstruction of 1.568 km of main heat supply networks in Kretinga, which increased reliability of heat supply to over 2,500 heat consumers, reduced heat losses in the pipelines by over 240 MWh per year, and thus reduced particulate matter and NOx emissions by over 150 kg per year. In 2018, the company also replaced more than 0.5 km of worn-out heat supply pipelines on its own, which also contributes to the reliability of heat supply and heat energy savings.

Since 1998, UAB „Kretingos šilumos tinklai“ has also been providing maintenance of internal heating and hot water systems in buildings. Currently, the company operates over 160 building systems in the Kretinga district. The system maintenance includes not only preparation for the heating season, elimination of faults and malfunctions, adjustment of the amount of heat supplied to the heating and hot water systems and maintenance of optimal modes, but also analysis of the consumption of heat in the buildings and processing of the data, providing recommendations and proposals for more efficient and economic use of heat inside the buildings. Currently, the monitoring and controlling system for heat meters is being implemented in some sub-stations of the buildings. In the future, this will support the optimisation of system maintenance, identify and correct faults quicker, and provide a wider analysis and optimal decision-making on heat consumption in buildings.

The main system parameters are provided in Table 3.5:

**Table 3.5: System parameters of Kretinga DH systems.**

Parameter	Measure units	Value	Comments
Location	Coordinates	55.88693, 21.24321	<a href="#">Kretinga – „Google“ žemėlapiai</a>
Country		Lithuania	
Length of pipelines	km	20.198	
Installed load	MW	55.6	
Number of Customers (Fig.4)	Units, total	3,900	Residents – 66%; Public institutions – 26%; Businesses – 8%.

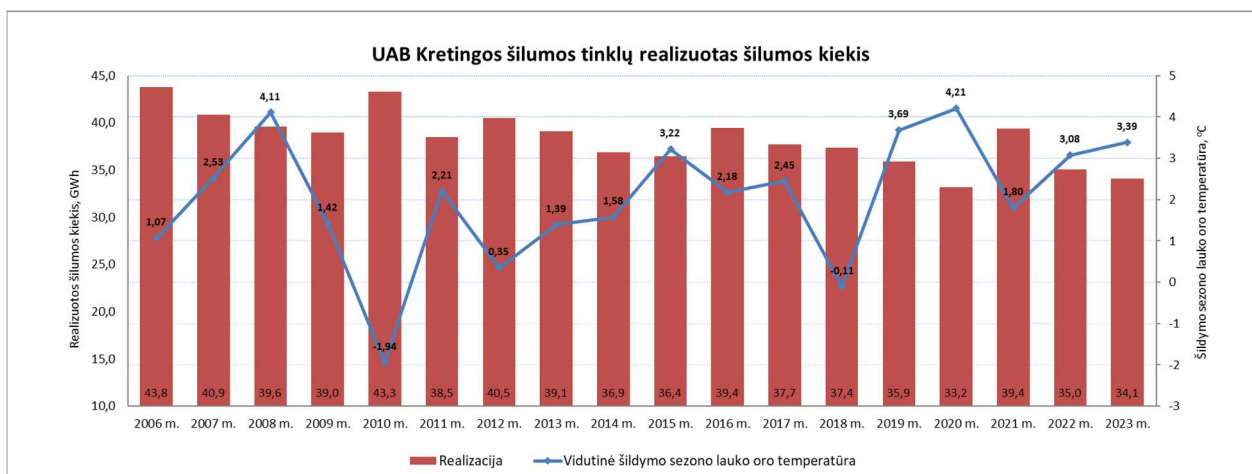
Temperature level (Flow temperature, return temperature)	°C	Non-heating season 67 – 46 (N) 45 – 41 (L)  Heating season 95 – 54 (N) 80 – 66 (L)	There are 2 groups of boiler-houses: with network (N) and local (L)
Pressure Level	Bar	5' – 3'	
Pipe losses (thermal insulation, pipe diameters)	%	17.18	
Grid topology			Mixed load control
Storage capacities (type, load, storage duration)	MW, MWh	0	None currently

### 3.4.1 Introduction

UAB Kretingos Šilumos Tinklai is a company in Lithuania, with a head office in Kretinga. It operates in the Electric Power Generation sector. UAB Kretingos Šilumos Tinklai was incorporated on September 30, 1998. 62 (2025) employees currently work for UAB Kretingos Šilumos Tinklai. In its most recent financial highlights, the company reported a net sales revenue drop of 1.35% in 2023.

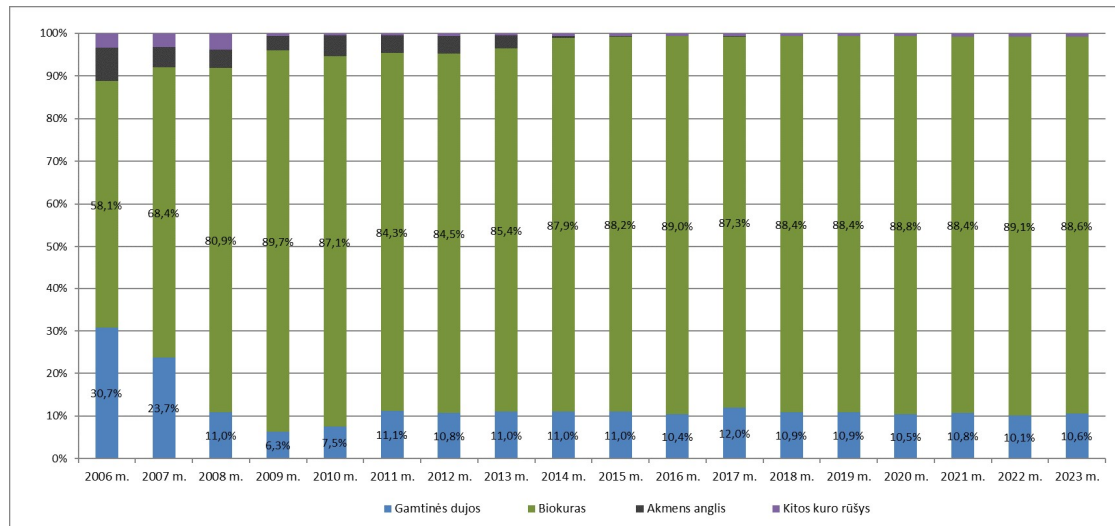
### 3.4.2 Technical Specifications of Kretinga District Heating company

Figure 3.20 below shows the volume of heat supplied to the network in GWh/a since 2006 vs. the average outside temperature during the heating season.



**Figure 3.20: The volume of heat supplied to the network in GWh/a during 2006-2023 vs. average outside temperature during heating season, °C.**

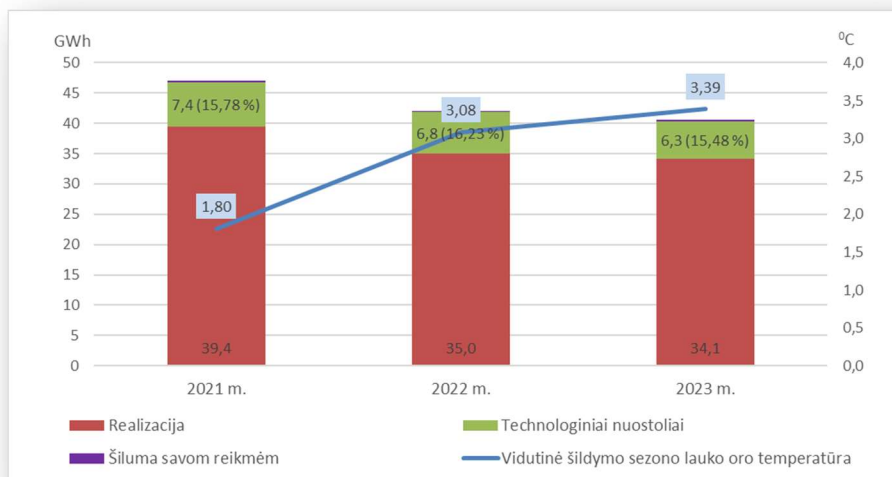
The dynamics of the share of the fuel types used in the boiler-houses of Kretinga DH company during the period 2006-2023 is presented in Figure 3.21.



**Figure 3.21: The share of the fuel types, %, used in the boiler-houses of Kretinga DH company during the period 2006-2023. (Here: ■ – natural gas, ■ – biomass, ■ – coal, and ■ – other).**

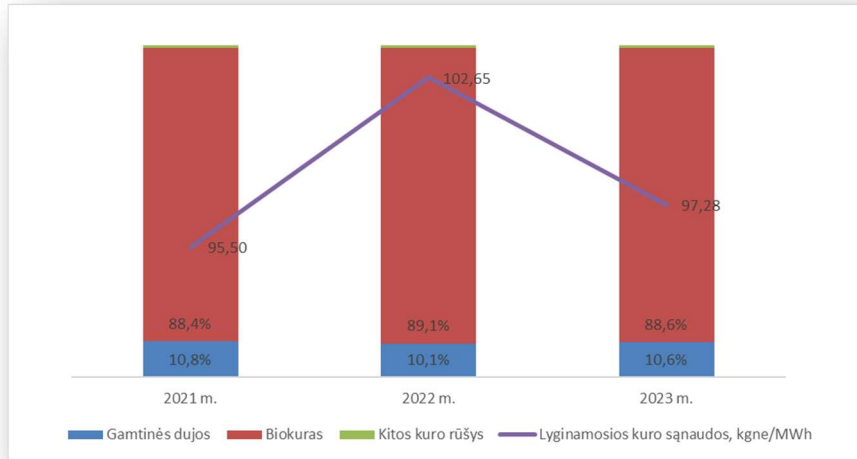
### Heat supply and fuel structure (data for year 2023)

34.1 thousand MWh of thermal energy was supplied to consumers in 2023, which is 0.945 thousand MWh less than in 2022. The share of thermal energy sales is 66% for residential customers, 26% for public institutions and 8% for businesses. The decrease in supplied heat is due to a 0.31 °C degree warmer average outdoor temperature during the heating season (Figure 3.22) and a 6 days shorter heating season for residents.



**Figure 3.22: Heat supply, heat for own needs and technological losses in GWh vs. average outdoor temperature during the heating season, °C (here ■ - heat supply, ■ - heat for own needs, ■ - technological losses).**

The fuel structure in 2023 has changed insignificantly (Figure 3.23). Biomass accounted for the largest share of 88.6% of the fuel mix, followed by natural gas at 10.6% and other fuels (LPG) at 0.8%.



**Figure 3.23: Technologic fuel structure, %, and comparative fuel consumption, ktoe/MWh (here ■ - natural gas, ■ - biomass, ■ - other types of fuel).**

Natural gas combustion generated 4,483 thousand MWh, wood chips - 34,928 thousand MWh, wood pellets – 0.86 thousand MWh, sawdust briquettes – 0.002 thousand MWh, and LPG – 0.309 thousand MWh of thermal energy.

### Installed capacities

Table 3.6 shows all heat sources and generators, fuel consumption and capacities by boiler-houses in Kretinga DH company.

**Table 3.6: Heat sources and generators, fuel consumption and capacities by boiler-houses in Kretinga DH company in 2022.**

No.	DH system/boiler-house Boiler	Installed boiler/ installation capacity, MW	Installed boiler-house capacity, MW	Max load of the boiler-house in 2023, MW	Installation/ overhaul year	Type of fuel	Boiler efficiency, %
1	<b>Kretinga DHS1.1*/ Boiler-house no1 (rezerve)</b>		13.2540	-			
	HOB KVG-4-150	4.6500			1987	NG	90%
	HOB KVG-4-150	4.6500			1987	NG	90%
	HOB VK-21	1.9770			1995	NG	92%
	HOB VK-21	1.9770			1996	NG	92%
2	<b>Kretinga DHS1.2*/ Boiler-house no2</b>		38.6900	9.2			
	HOB "Kalvis 2300M1"	2.3000			2014	chips	80%
	HOB "Kalvis 5000MK"	5.0000			2012	chips	85%

	HOB KVG-6,5-150	7.5600					
	HOB KV-GM-10-150	11.6300			1989	NG	85%
	HOB "KVV05.07"	5.0000			2020/2023	chips	93%
	HOB KAISTRA 5000	5.0000			2006/2023	chips	86%
	Condensing economizer flue gas - water	2.2000					
<b>3</b>	<b>Salantai DHS1/ Boiler-house no3</b>		<b>1.9500</b>	<b>0.65</b>			
	HOB "Kalvis-950M1"	0.9500			2014	Chips	77%
	HOB KAITEC-3a-1000	1.0000			2007	chips	75%
<b>4</b>	<b>Salantai DHS2/ Boiler-house no4</b>		<b>1.2200</b>	<b>0.32</b>			
	HOB "Kalvis-720M-1"	0.7200			2010	Chips	79%
	HOB UT-500	0.5000			2000	chips	79%
<b>5</b>	<b>Kretinga DHS2/ Boiler-house no5</b>		<b>2.4770</b>	<b>0.48</b>			
	HOB VK-21	1.9770			1991	NG	88%
	HOB Buderus Logano plus KB372-250H	0.2500			2020	NG	98%
	HOB Buderus Logano plus KB372-250H	0.2500			2020	NG	98%
<b>6</b>	<b>Boiler-house of Kindergaten "Eglutė"</b>		<b>0.0740</b>	<b>0.07</b>			
	HOB BOSCH K48-8E	0.0480					
	HOB WOLF FNG-26	0.0260					
<b>7</b>	<b>Vydantai DHS/ Boiler-house no8</b>		<b>0.6100</b>	<b>0.28</b>			
	HOB REX35F	0.3500					
	HOB WOLF MK-1-260	0.2600					
<b>8</b>	<b>Kretinga DHS3/ Boiler-house no9</b>		<b>0.7140</b>	<b>0.28</b>			
	HOB WOLF-MKS-340	0.3400					
	HOB SEVEM-12	0.1870					
	HOB SEVEM-12	0.1870					
<b>9</b>	<b>Kretinga DHS4/ Boiler-house no10</b>		<b>0.3600</b>	<b>0.13</b>			
	HOB SEVEM-11	0.1700					
	HOB WOLF-MKS-190	0.1900					
<b>10</b>	<b>Boiler-house no11</b>		<b>0.3400</b>	<b>0.09</b>			
	HOB SEVEM-11	0.1700					
	HOB SEVEM-11	0.1700					
<b>11</b>	<b>Darbėnai DHS/ Darbėnai boiler-house</b>		<b>0.4200</b>	<b>0.25</b>			
	HOB GD-WB 70	0.0700					
	HOB HAMONT CATfire 350KBT	0.3500					
<b>12</b>	<b>Grūšlaukė DHS/ Grūšlaukė boiler-house</b>		<b>0.1400</b>	<b>0.08</b>			
	HOB UT-100	0.1000					

	HOB UT-150	0.0400					
<b>13</b>	<b>Jokūbavas DHS/ Jokūbavas boiler-house</b>		<b>0.4500</b>	<b>0.12</b>			
	HOB UT-200	0.2000					
	HOB ARIMAX BIO 300	0.2500					
<b>14</b>	<b>Laukžemē Boiler-house no 2/ incl. heat pumps</b>		<b>0.0400</b>	<b>0.03</b>			
			<b>0.0240</b>				
	HOB GD-EKO-40	0.0400					
	Heat pump WH-UX12HE8	0.0120					
	Heat Pump WH-UX12HE8	0.0120					
<b>15</b>	<b>Rūdaičiai DHS/ Rūdaičiai boiler-house</b>		<b>0.2000</b>	<b>0.09</b>			
	HOB GD-WB 100	0.1000					
	HOB GD-WB 100	0.1000					
<b>16</b>	<b>Kūlupėnai DHS/ Kūlupėnai boiler-house</b>		<b>0.3000</b>	<b>0.1</b>			
	HOB VC 115/140	0.1500					
	HOB VC 115/140	0.1500					
<b>17</b>	<b>Boiler-house of S.Daukantas school</b>		<b>0.3400</b>	<b>0.3</b>			
	HOB VIESSMANN 170	0.1700					
	HOB VIESSMANN 170	0.1700					
<b>18</b>	<b>Kartena DHS/ Kartena boiler-house</b>		<b>0.8450</b>	<b>0.28</b>			
	HOB HAMONT CATfire 500KBT	0.5000					
	HOB VIESSMANN 340	0.3450					
<b>19</b>	<b>Baubliai boiler-house</b>		<b>0.1060</b>	<b>0.05</b>			
	HOB GD-WB 70	0.0700					
	HOB Pellet uni 36	0.0360					
<b>20</b>	<b>Salantai DHS3 / Boiler- house of Salantai eldership</b>		<b>0.1400</b>	<b>0.07</b>			
	HOB GD-WB 70	0.0700					
	<b>HOB VIESSMANN</b>	<b>0.0700</b>					
<b>21</b>	<b>Salantai DHS4/ Salantai container boiler-house</b>		<b>0.0500</b>	<b>0.03</b>			
	HOB UT-50	0.0500					
<b>22</b>	<b>Kurmaičiai boiler-house</b>		<b>0.1800</b>	<b>0.04</b>			
	HOB Buderus Logano G 334	0.0900					
	HOB Buderus Logano G 334	0.0900					
<b>23</b>	<b>Šukės boiler-house</b>		<b>0.0400</b>	<b>0.03</b>			
	HOB GD-BIO-40	0.0400					
<b>24</b>	<b>Raguviškės boiler-house</b>		<b>0.0900</b>	<b>0.03</b>			
	Heiztechnik Q EKO	0.0700					
	KALVIS -2 - 20	0.0200					
<b>25</b>	<b>Boiler-house of Kartena Culture Centre</b>		<b>0.1000</b>	<b>0.02</b>			

	HOB WBS-40	0.0400					
	HOB WBS-40	0.0400					
	KALVIS -2 - 20	0.0200					

Red – boilers not in operation; Green – boilers planned/to be replaced

Nearly 75% of primary fuel energy is consumed in Boiler no 2, supplying to Kretinga town network. 40.582 thousand MWh of thermal energy was generated in 2023.

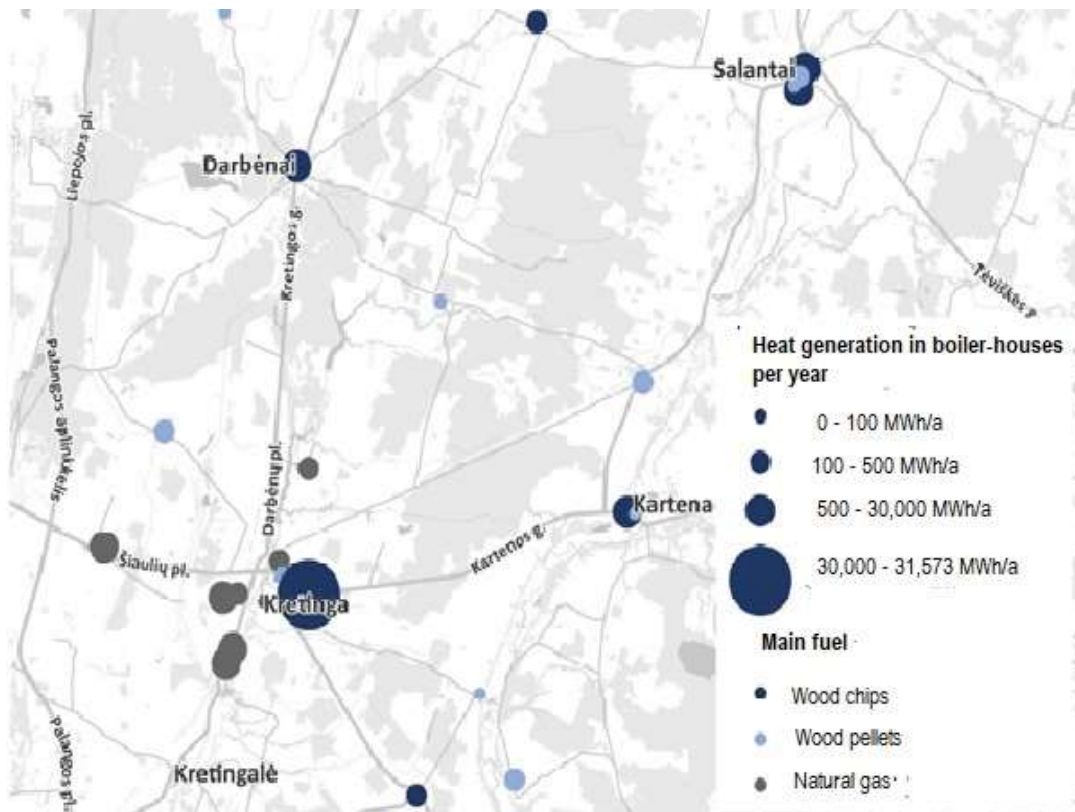


Figure 3.24: The map of all boiler houses in Kretinga District Municipality owned by Kretinga DH company by annual heat generation and types of fuel.

Table 3.7 shows the summary of the pipelines of Kretinga DH company. The share of renovated pipelines in Kretinga DH company is 57%.

Table 3.7: Summary data on heat pipelines of Kretinga DH networks in 2024.

Boiler-house	Pipeline length, m	Pipeline during the non-heating season, m	Channel-free pipelines, m	Share of channel-free pipelines, %	Pipelines volume, m <sup>3</sup>	Estimated losses due to leakage, m <sup>3</sup>	Estimated losses in the pipelines, MWh
Darbėnai boiler-house	485.80		445.80	91.77	3.80	22.80	72.50

Container boiler-house, Salantai	18.00		18.00	100.00	0.03	0.10	1.70
Grūšlaukė boiler-house	504.00		140.00	27.78	2.60	23.50	74.20
Jokūbavas boiler-house	91.00		47.00	51.65	0.40	2.60	14.10
Boiler-house no 2	14703.10	14494.60	8392.40	57.08	575.70	6287.80	5596.20
Boiler-house no 3	990.20		703.20	71.02	27.60	189.60	201.40
Boiler-house no 4	1077.00		575.00	53.39	10.00	73.00	198.00
Boiler-house no 5	669.50	642.50	167.50	25.02	12.10	190.50	253.10
Boiler-house no 8	734.70		412.70	56.17	8.00	3.00	136.70
Boiler-house no 9	109.70	109.70	68.00	61.99	0.70	9.10	22.10
Boiler-house no 10	111.00	111.00	111.00	100.00	0.40	3.80	23.70
Kartena boiler-house	347.20		133.20	38.36	2.10	17.40	48.30
Kūlupėnai boiler-house	105.00		46.00	43.81	0.40	3.10	14.30
Rūdaičiai boiler-house	224.60		224.60	100.00	2.10	10.10	29.20
Salantai eldership boiler-house	27.00		27.00	100.00	0.03	0.10	2.20
<b>Total:</b>	<b>20197.80</b>	<b>15357.80</b>	<b>11511.40</b>	<b>56.99</b>	<b>645.96</b>	<b>6836.50</b>	<b>6687.70</b>

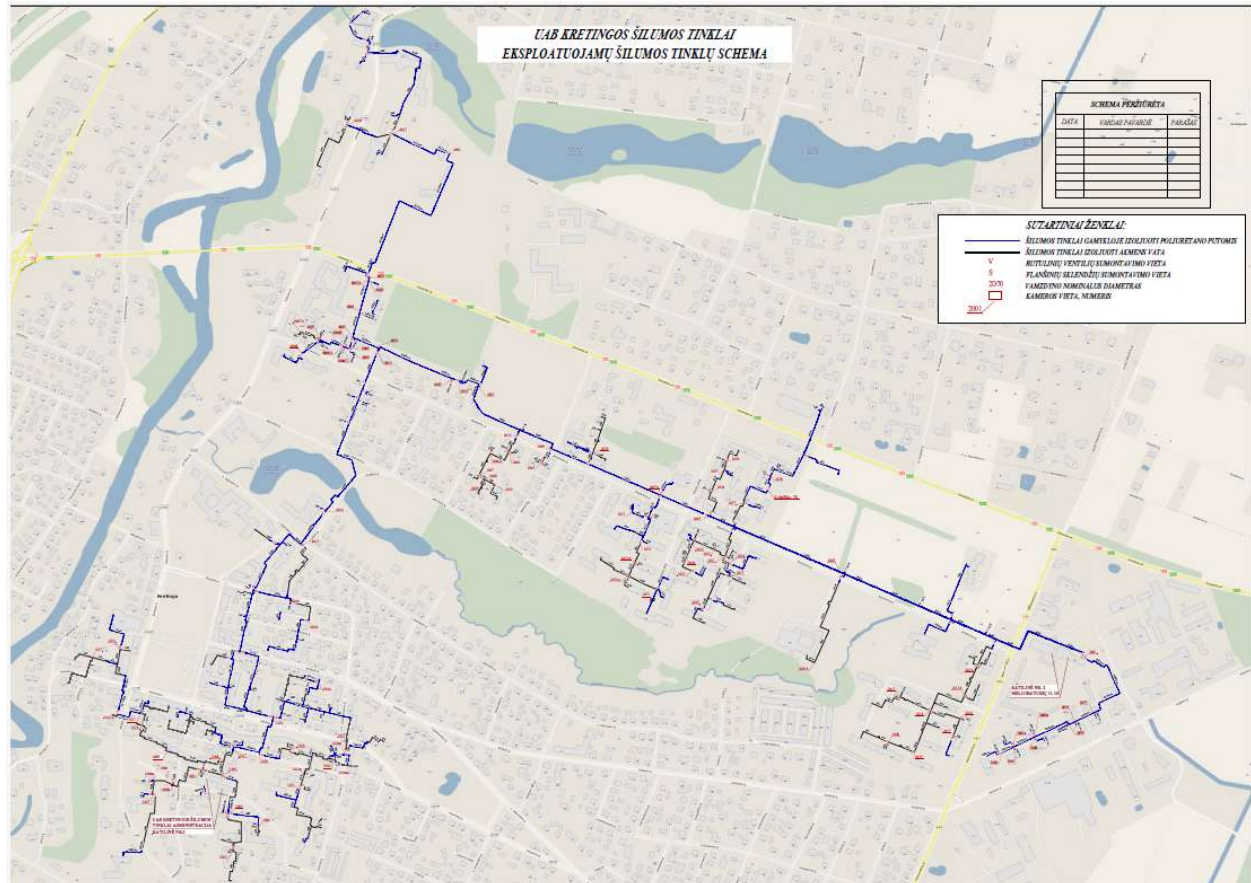


Figure 3.25: The scheme of the main pipeline in Kretinga town (Boiler-houses no 1 and 2).

### Operating parameters

There are two groups of boiler-houses operated under Kretinga DH company – with networks (N) and local (L). Thus, temperature levels can be divided for these two types as well as difference for heating season and non-heating season. Temperature level (Flow temperature, return temperature) for non-heating season is 67 – 46 °C (N) and 45 – 41 °C (L). For heating season temperatures are 95 – 54 °C (N) and 80 – 66 °C (L).

Pressure levels in the networks are 5' – 3' bar. Pipe losses are 17.18 %. There are no heat storages in Kretinga DH systems.

### Digitalization and monitoring

The company's software includes:

- a heat calculation program,
- accounting software,
- a document management system, and
- a service management system.

Digital production logs have been installed in the boiler house.

The boiler houses are operating SCADA systems, which allow monitoring and control of the boilers and the economizer. The company operates 27 operational boiler houses and only 4 are equipped with remote monitoring of meters.

The use of MS Planner software has been introduced for the control of the organisation of operations and the allocation of work.

### 3.4.3 CO<sub>2</sub> Emissions

Due to the fact that boilers in Kretinga DH company do not exceed 10 MW capacity, DNV Lithuania UAB, which represents the international certification and assessment body DNV and is responsible for providing greenhouse gas (GHG) emissions verification services in Lithuania, confirms that Verification Body DNV has verified the CO<sub>2</sub> emissions report for Kretinga boiler-house no 2 and confirms 0 t CO<sub>2</sub> emissions of GHG as for 2023.

As with all DH systems in Lithuania, Kretinga DH company must perform Monitoring of the technological processes of economic operators and sources of pollution by non-permanent measurements of monitoring of emissions/discharges. The measurements were taken on: carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), particle matter (PM) and sulphuric anhydride (SO<sub>2</sub>). The results of the measurement show that conditions are in line with the technical regulations in the years 2022 and 2023.

### 3.4.4 Inefficiencies and Improvements

There are two sources of inefficiencies in Kretinga DH company and Kretinga district municipality:

- Still not replaced heat supply pipelines;
- Non-renovated buildings, which are the consumers of district heating.

The following measures should be implemented to improve efficiency:

Kretinga DH company together with Kretinga District Municipality are constantly working on the improvement of energy efficiency in district heating. The municipality is responsible for the renovation of residential and public buildings, which reduces demand and improves the efficiency of energy consumption.

On the other hand, Kretinga DH company was constantly performing the following actions, which led to improved efficiency and use of RES in the municipality:

- Transfer to biomass burning in DH sector;
- Improvement of energy efficiency in the operation of boiler houses;
- Replacement of heat pipelines;
- Implementation of remote data reading system.

### 3.4.5 Conclusions and Outlook

Kretinga District heating company UAB „Kretingos šilumos tinklai“ operates 20,209 km of outdoor heating pipelines in Kretinga town and district. Thermal energy for heating and hot water is supplied to over 250 buildings or 3,567 heat consumers.

The company has 28 boiler houses with a wide variety of operating installations, including over 50 different water heating boilers, auxiliary equipment for optimising and controlling operating modes, air cleaning equipment, automation equipment, and various other auxiliary facilities. All these were constantly updated and adapted, as well as improving technical parameters in response to modern development trends, and more economic fuels of the time.

The company was one of the first in Lithuania, and probably the first in the western part of the country, to introduce technologies that allowed the introduction and combustion of biomass fuel, i.e. the residual product of wood processing, in a partially automated way. The company started using biomass pellets in small boiler houses in 2003 and 2004. Kretinga DH company was one of the first to reach the threshold of almost 90% biomass fuels in the total fuel balance.

The switch from natural gas to biomass as the main fuel has also been accompanied by the reduction of combustion emissions, i.e. the installation of multi-cyclone air purifiers, which capture 87-90% of the solid particles in the flue gas. In 2011 the company installed a new generation industrial condensing economiser, which had several purposes: improving the efficiency of biomass boilers operation, as well as trapping around 63% of the solid particles in the flue gases after the multi-cyclone.

Each year, the company invests in upgrading installations in boiler houses and heat supply networks to ensure a reliable and cost-effective supply of thermal energy to consumers. This saves fuel and reduces losses in the network.

Reconstruction of the main heat pipelines of the boiler house No.2 in Kretinga town resulted in the reconstruction of 1.568 km of main heat supply networks in Kretinga, which increased reliability of heat supply to over 2,500 heat consumers, reduced heat losses in the pipelines by over 240 MWh per year, and thus reduced particulate matter and NO<sub>x</sub> emissions by over 150 kg per year.

Since 1998, UAB „Kretingos šilumos tinklai“ has also been providing maintenance of internal heating and hot water systems in buildings. Currently, the company operates over 160 building systems in the Kretinga district. The system maintenance includes not only preparation for the heating season, elimination of faults and malfunctions, adjustment of the amount of heat supplied to the heating and hot water systems and maintenance of optimal modes, but also analysis of the consumption of heat in the buildings and processing of the data, providing recommendations and proposals for more efficient and economic use of heat inside the buildings.

Currently, the monitoring and controlling system for heat meters is being implemented in some sub-stations of the buildings. In the future, this will support the optimisation of system maintenance, identify and correct faults quicker, and provide a wider analysis and optimal decision-making on heat consumption in buildings.

### **3.5 IWEN: Rostock – Germany**

The Hanseatic City of Rostock operates one of the largest and most established district heating systems (DHS) in northeastern Germany. With a pipeline length of approximately 421 km and a thermal capacity of 576 MW, the system supplies around two-thirds of all households, as well as large parts of the city's commercial and public infrastructure.

The DHS is primarily based on fossil fuels. Its main heat source is the combined heat and power (CHP) plant in Marienehe, which operates on natural gas and contributes roughly 70% of the district heat supply. An additional 150 MW of heat is sourced from the hard coal-fired power plant in the port area, categorized as "waste heat" and accounted with an emission factor of 0 g CO<sub>2</sub>/kWh. This results in an officially certified specific CO<sub>2</sub> value of 132.8 g/kWh—low on paper, but not representative of the system's true carbon footprint.

The network is designed as a high-temperature hot water system with flow temperatures ranging from 85 °C in summer to 125 °C in winter, and operates under medium pressure (typically 6–10 bar supply). Such conditions limit the integration of low-temperature renewable technologies. The average annual energy delivered through the system was 700–750 GWh in recent years, with about 71% serving residential users and 29% serving industry and commerce.

One of the key assets of the DHS is its newly operational 2 GWh hot water storage tank, enabling load balancing and weekend buffering. Additionally, a power-to-heat (PtH) system has been commissioned to make use of surplus electricity from renewables, feeding directly into the district heating.

One of the key assets of the DHS is its newly operational 2 GWh hot water storage tank, enabling load balancing and weekend buffering. Additionally, a power-to-heat (PtH) system has been commissioned to make use of surplus electricity from renewables, feeding directly into the district heating grid.

In summary, Rostock’s district heating system is technically mature, well-integrated into the urban infrastructure, and provides high supply security. At the same time, it remains highly carbon-intensive and structurally reliant on high-temperature fossil-based generation. This baseline assessment provides the foundation for a subsequent potential analysis focused on decarbonization pathways and system transformation (deliverable D2.3).

**Table 3.8: Summary of Rostock DHS parameter.**

Parameter	Value	Comment
Location	Hansestadt Rostock	
Country	Germany	
Length [km]	421	
Installed Load [MW]	576	
No. Customers	78,000	2/3 of all private households
Temperature Flow [°C]	70 – 130	
Temperature Return [°C]	< 60	
Pressure Supply [bar]	13	
Pressure Return [bar]	7 - 12	
Heat sources	2	70% CHP 29% waste heat from coal-fired power plant < 1% RE
Pipe losses [%]		
Pipe diameters [mm]		
Network Design	Main line with various branches	
Storage capacities [m <sup>3</sup> ]	45,000	Hot-water storage tank
Power density [MW/km]	1.4	

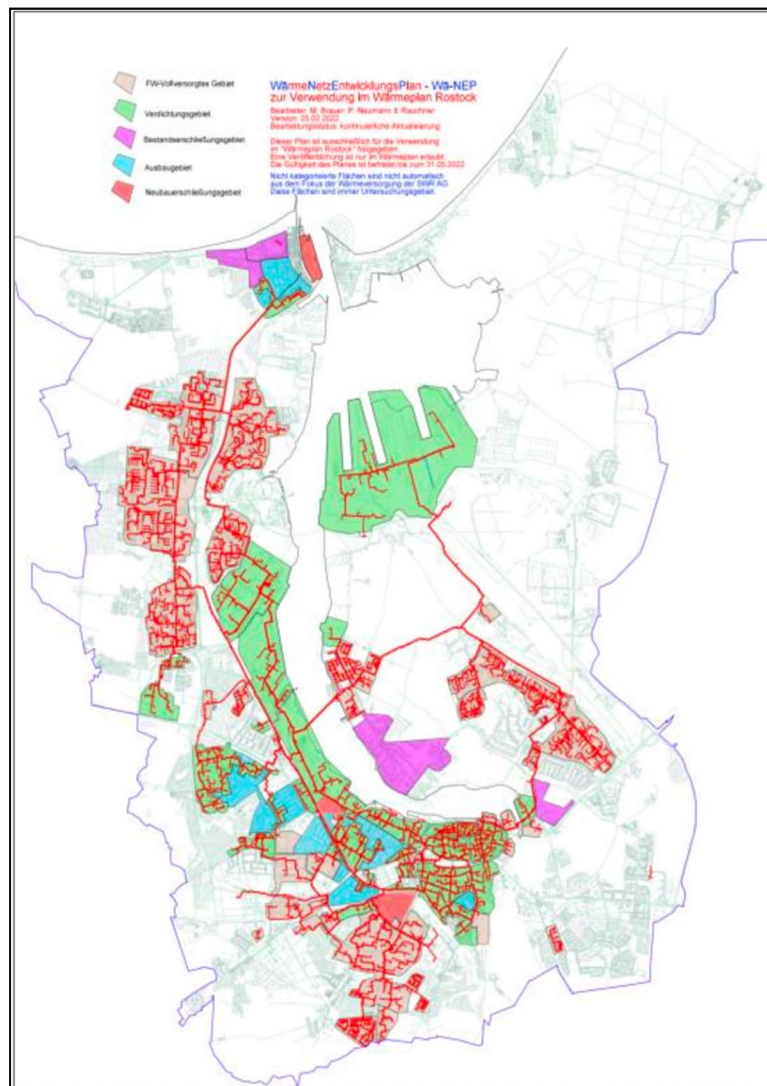
### 3.5.1 Introduction

The Hanseatic and University City of Rostock operates one of the most significant district heating networks in Mecklenburg-Vorpommern. It supplies large parts of the city with centrally generated heat and plays a key role in the local energy transition. This report provides a comprehensive overview of the current state of Rostock's district heating system, highlighting technical specifications, digitization aspects, CO<sub>2</sub> emissions, and efficiency considerations.

### 3.5.2 Technical Specifications of DHS Rostock

#### District Heating Network and Pipeline Length

The district heating network (see Figure 3.26) of the district heating supply company Stadtwerke Rostock AG (SWR AG) covers a pipeline length of approximately 421 kilometres. It is a branched hot water network that spans nearly the entire city area, structured around a mainline grid with various branches, serving residential, commercial, and public buildings.



**Figure 3.26: DHS network Rostock [1]. The network plan divides the city districts into six categories of network development: densification area (green), expansion area (blue), existing**

**development area (purple), new development area (red), fully developed FW areas (brown) and white areas.**

### **Installed Heating Capacity**

SWR AG currently supplies around two thirds of all households with district heating from the natural gas-fired gas and steam turbine plant (CCGT plant) in Marienehe via the district heating network. As the process involves combined heat and power (CHP), electricity and heat are produced simultaneously. As a result, utilization rates of approx. 85 % can be achieved. The total output is 108 MW electrical and 120 MW thermal (fed into the DHS). In order to cover peak heating requirements in winter, additional modernized hot water generators fired with natural gas with a total thermal output of 284 MW are available [2].



**Figure 3.27: Combined cycle gas turbine (CCGT) plant in Marienehe.**

Part of the district heating is obtained by extracting waste heat from electricity production from the hard coal-fired power plant in the Rostock seaport and feeding it into the central grid. The power plant is owned by the energy companies EnBW AG and RheinEnergie AG. The power plant for electricity generation is designed for district heat extraction of up to 300 MW, of which around 150 MW has currently been realized [3]. The proportion of renewable energy supply systems, such as small combined heat and power plants or heat pumps, is currently less than 1 %. The district heating network has a heat output of 576 MW. In 2023, the DHS system provided an energy of about 700 GWh, 71% of which was for private households and 29% for industry and commerce [4].

### **Operating Parameters: Temperature and Pressure**

SWR AG operates various heating networks with different temperature and pressure levels in its supply area. SWR AG provides the necessary heating water at the transfer station with network-dependent temperatures and pressures. The flow temperature of the district heating network varies seasonally (around 85 °C in summer and 125 °C in winter).

The operating pressures in the district heating network of Rostock are designed according to the principles of medium-pressure systems, typically ranging between 6 to 10 bar on the flow side and around 4 to 8 bar on the return side. These pressures are not universally fixed across the network but are instead adjusted based on specific conditions such as pipe length, elevation differences, and the hydraulic resistance of the system.

Pressure levels are maintained using expansion or pressure maintenance systems to ensure operational safety and consistent delivery, even in distant or elevated parts of the city. The exact values for flow and return pressure at each consumer connection point are usually defined in the individual House Supply Agreements, not published in the general Technical Connection Conditions (TAB) [5]. These documents, issued by Stadtwerke Rostock, comply with the national AVBFernwärmeV [6] and follow AGFW [7] and DIN4747 [8] guidelines, ensuring that all components are rated for medium-pressure operation (typically up to 16 bar).

### Heat Storage: Capacity and Duration

Since the start of 2023, Rostock operates a large, unpressurized hot-water storage tank that significantly boosts the flexibility of its district heating network. The steel tank stands approximately 55 meters high and holds around 45 million Liters (45,000 m<sup>3</sup>) of hot water, which is equivalent to a capacity of 2kWh. This is sufficient to supply the city for an entire weekend during low-load periods [9]. When fully charged, the water reaches temperatures of up to 98 °C, aligning well with the district heating system's maximum designed flow temperature of 125 °C [2, 3].



**Figure 3.28: The heat storage tank together with the power-to-heat system in Marienehe.**

The tank's total storage capacity is approximately 2 GWh, enabling it to autonomously support Rostock's heat demand for about 48 hours, effectively acting as a weekend buffer. Directly adjacent to the storage is a Power-to-Heat (PtH) plant, which converts surplus electricity from wind and solar installations into heat. Surplus heat is then used to charge the tank, effectively coupling renewable energy generation to district heating needs.

Construction of the system began in early 2020 and, after a successful testing period in spring 2022, the storage entered regular operational service in December 2022. The synergy between the PtH plant and the

hot-water storage makes it possible to better balance renewable energy input, reduce dependence on fossil-fuel-fired peak-load boilers, and enhance the overall reliability and sustainability of Rostock's heat supply system.

Furthermore, SWR AG plans to build a pit thermal energy storage (PTES) in the northeast of the city [10]. This pit storage which will be buried underground in the shape of a pyramid will have a size of over 80.000 m<sup>2</sup> and will store over 500.000 m<sup>3</sup> litres of 98 °C hot water. It will function as seasonal storage, storing excess heat for the winter months. With a planned storage capacity of 33 GWh, it would be enough to supply the whole of Rostock for up to a month.

### **Digitization and Monitoring**

The WARAN project [11] ("Wärme anbinden und netzdienlich nutzen" – Integrating and Grid-Serving Usage of Heat), as a part of the DigENet-II funding call [12] is a pioneering German initiative that addresses the urgent need to digitalize the heating sector as part of the broader energy transition. While the electricity sector has already made significant progress in smart metering and digital infrastructure, the heating sector – despite being responsible for over 58% of Rostock's total energy consumption [1] – remains largely analogue and lacks the transparency and flexibility necessary for an integrated energy system. WARAN is tightly aligned with Germany's current regulatory momentum—e.g., §14a EnWG [13], GNDEW [14], the Building Energy Act (GEG) [15], and municipal heat planning laws—all of which push toward a carbon-neutral heating system. The project feeds its findings directly into the standardization and policy development processes by working with national bodies such as the Federal Network Agency (BNetzA), the Federal Office for Information Security (BSI), and the Federal Ministry for Economic Affairs and Climate Action (BMWK).

WARAN aims to develop and test a standardized infrastructure based on intelligent metering systems (iMSys), using the communication capabilities of Smart Meter Gateways (SMGW) – particularly the CLS channel (Controllable Local Systems) – to integrate and remotely control heating systems such as heat pumps, electric boilers, and transfer stations within district heating and local heating networks [11]. This enables grid-responsive and market-oriented operation of power-to-heat technologies and facilitates deeper sector coupling between electricity and heat.

The project's central goal is to make heating networks transparent, controllable, and integrated within Germany's digital energy infrastructure. It involves lab experiments and real-world field tests that demonstrate how smart metering technology can be used to unlock flexibility potentials from buildings and heating systems, enabling them to actively participate in energy markets and support grid stability.

SWR AG is a key associated partner in the WARAN consortium providing technical expertise from both grid operations and metering system management.

### **3.5.3 CO<sub>2</sub> Emissions**

The annual and activity report [16] in accordance with the Energy Industry Act (EnWG) [13] for 2022 gives a CO<sub>2</sub> value of 235 g/MWh for the entire Marienehe CHP plant, which complies with the prescribed emission values. Due to the form of the legally prescribed type of balancing, it is possible to include the use of waste heat from the hard coal-fired power plant at the port with an emission factor of 0 g/MWh. In combination with the above emission factor of Marienehe, the result is a specific CO<sub>2</sub> emission value of 132,8 g/MWh for district heating which was certified by TU Dresden in 2017 and is valid until 2027 [17].

As a temporary measure, as long as fossil fuels have not yet been replaced by renewable alternatives, greenhouse gas emissions from heat production are offset by purchasing CO<sub>2</sub> compensation certificates from certified agencies [1].

### 3.5.4 Inefficiencies and Improvements

The current district heating system in Rostock shows several inefficiencies that hinder its transition to climate neutrality. As outlined in the “Wärmeplan Rostock 2035,” [1] the system is still heavily reliant on fossil fuels, primarily natural gas and coal. Although the official CO<sub>2</sub> emissions factor for district heating appears low, this is due to favourable accounting rules - particularly the assumption that waste heat from the coal-fired power plant carries no emissions. This creates a misleading picture of the system’s actual climate impact.

Another challenge lies in the limited capacity for expanding the existing district heating network. In areas with low building density, network extension is economically unfeasible and technically inefficient. Additionally, the current system operates at high temperatures—often above 100 °C—posing a barrier to integrating low-temperature technologies such as large-scale heat pumps. Heat losses through the pipe infrastructure, especially in older, poorly insulated sections, further reduce the system’s overall efficiency. Moreover, the share of renewable energy sources in heat generation remains negligible, currently below 1%.

To address these inefficiencies, the city has developed a broad set of optimization strategies. Central to this is the decarbonization of heat generation. This will involve deploying large-scale heat pumps that harness waste and environmental heat from sources such as treated wastewater, the Warnow River, and the Baltic Sea. Some of these installations are expected to provide up to 100 MW of thermal output per site. These systems will be supplemented by the recovery of industrial waste heat and the use of seasonal large-scale heat storage, including the PTES mentioned above. Such storage enables the effective use of surplus summer heat in winter.

Modernization of the district heating network itself is another priority. The city plans to lower network temperatures to reduce heat losses and facilitate the integration of more efficient technologies. However, as the cost-benefit ratio and the CO<sub>2</sub> reductions that can be achieved by lowering the grid temperature are less favourable than when converting to climate-neutral heat generators, investments will first be made in the transformation of heat generators in the short and medium term. Additionally, the network will be expanded and densified in selected urban districts by up to 200 GWh of additional capacity by 2035.

New technologies are also being considered, including the potential integration of solar thermal systems. However, technical and economic constraints currently limit their viability for the core network. Biomass is intended primarily for peak load coverage, through heating plants and biogas facilities, but its limited availability means it will play a secondary role.

Beyond the supply side, significant efficiency improvements are targeted within the building stock. These include an increased renovation rate of 1.2% per year and the promotion of heat recovery and optimized internal distribution systems. The plan also emphasizes the importance of reducing peak demand during winter, in order to stabilize the heat supply and maintain affordability. The insulation of the pipes and the installation method are parameters that can be used to further reduce heat loss. Optimizations take place here in the course of pipe renewals. New pipes are installed to the best possible insulation standard. The entire heating network and, in particular, the old stock of above-ground base and underground pipes are regularly inspected, e.g. by means of aerial surveys with thermographic analysis. Damaged areas are identified and repaired promptly. The route sections in the old stock with the highest heat losses have top priority in the network operator’s ongoing maintenance program. The unavoidable physical heat losses of the network are thus continuously optimized.

Finally, the success of the transformation process depends on robust governance. The city has introduced a district heating development plan and is coordinating with public authorities and utilities. It also emphasizes early engagement with stakeholders and long-term land use planning to secure locations for renewable energy production and storage infrastructure.

### 3.5.5 Conclusions and Outlook

The Hanseatic City of Rostock operates a highly capable and centralized district heating infrastructure, comprising over 400 km of network length and a total installed thermal capacity of around 576 MW. However, the current heat generation still relies almost entirely on fossil fuels—primarily natural gas and hard coal—posing a substantial challenge to the city’s target of achieving a climate-neutral heat supply by 2035. While the official CO<sub>2</sub> emission factor of the system is certified at only 132.8 g/kWh, this figure benefits from accounting rules (e.g., attributing zero emissions to industrial waste heat) and does not fully reflect the system’s real climate impact. Notable progress has been made: a 2 GWh hot water storage tank, a power-to-heat system, and participation in the WARAN digitization project highlight successful innovation. However, significant issues remain. The share of renewable energy in the DH system is still less than 1%, temperatures in the network are too high to support low-temperature technologies, and heat losses undermine efficiency. Moreover, the building stock still holds substantial potential for thermal improvements.

Rostock’s heat transition will require parallel transformations across the supply, infrastructure, and demand sides. Key technical priorities include the integration of large-scale environmental heat sources—such as treated wastewater, the Warnow River, and the Baltic Sea—via industrial-scale heat pumps. These will be supported by seasonal large-volume thermal storage (e.g., ground-level pit storage up to 33 GWh), allowing excess summer heat to be used during winter. The district heating grid will be strategically expanded and densified, with an additional 200 GWh of capacity planned by 2035. For areas where expansion is not viable, decentralized networks and building-specific renewable solutions will be needed. While solar thermal applications are currently deemed unsuitable for the core DH system due to storage limitations, their integration into local island networks remains under evaluation. A more detailed analysis of the potential of integrating renewable energies into the district heating system will be conducted as part of the deliverable D2.3.

Strong governance is critical. This includes land-use planning, investment roadmaps, and binding responsibilities. A comprehensive and coordinated approach - led by the city administration, public utilities, housing associations, and key stakeholders - is essential to realize a sustainable, socially acceptable, and resilient future heat supply for Rostock.

### 3.6 LNU: Kosta – Sweden

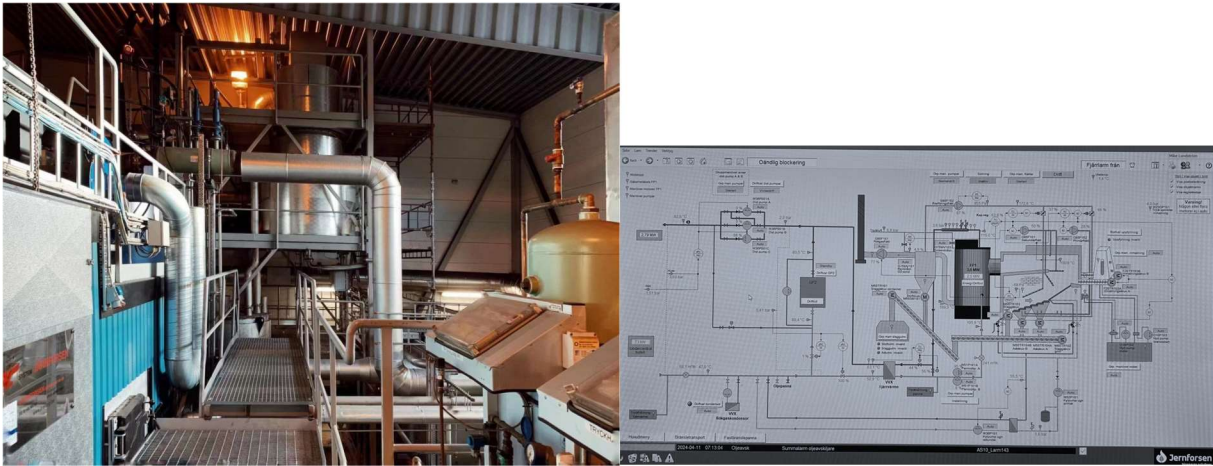


Figure 3.29: Side view of the Kosta 3MWth biomass boiler and ITK flue gas condenser, and the process controlling system. Photos made by Leteng Lin

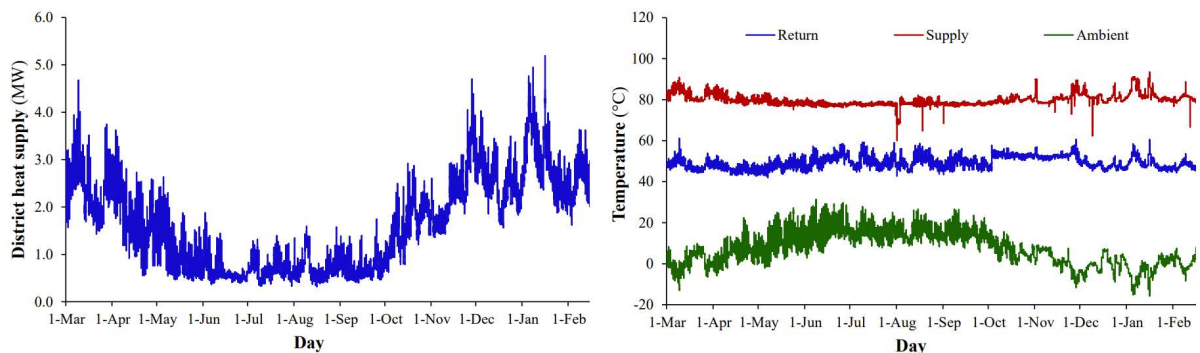


Figure 3.30: District heat production (left) and ambient-, supply- and return temperatures (right) in Kosta DH system during March 1st, 2023 - February 29th, 2024.

Parameter	Value	Comment
Location	Stora Vägen 104, Kosta	
Country	Sweden	
Length [km]	10	
Installed Load [MW]	3	total heat supply is 14.8 GWh in 2023
No. Customers	200 private houses, 19 community buildings, 14 housing company operated buildings, 2 hotels, 1 Glass factory, and 1 Sport Arena	

Temperature Flow [°C]	85	
Temperature Return [°C]	45	
Pressure Supply [bar]	3.5	*
Pressure Return [bar]		
Heat sources	1	biomass-fired boiler
Pipe losses [%]	7-11	
Pipe diameters [mm]	25-150	Depending on the locations and connections from the heat supply side to the end users in the grip
Network Design	Traditional network design	
Storage capacities [m <sup>3</sup> ]		
Power density [MW/km]		

\* The boiler design pressure 6bar. The grid operation pressure is about 3.5bar on the supply side, which is, however, varied and regulated based on the need of 1.5 bar as bottom setting located at the specific measuring spots closer to the far end of the grid.

### **Digitalization and control (remote monitoring, smart control systems):**

Remote monitoring integrated by Jenforsen boiler manufacturing.

#### **3.6.1 CO<sub>2</sub> Emissions**

Since biomass is considered a carbon-neutral fuel, the Kosta plant is now recognized as a carbon-neutral facility, particularly as it utilizes green electricity to meet its operational needs. Achieving negative carbon emissions is possible with the application of carbon capture and storage technologies, a solution currently being implemented in large-scale biomass combined heat and power plants in Sweden but not yet feasible for smaller-scale operations.

Further contributions to carbon mitigation in the energy system could be realized through poly-generation approaches, such as electricity cogeneration and biochar co-production. Renovations or integrations of existing plants could enable these advancements. For instance, cogenerated green electricity could replace fossil-based electricity, while biochar could serve as a carbon sink by improving soil quality, offering simultaneous environmental benefits.

A recent paper [18] that we published has simulated and investigated extensively on the potential and feasibility of Organic Rankine Cycle integration with Kosta plant.

#### **3.6.2 Energy inefficiencies**

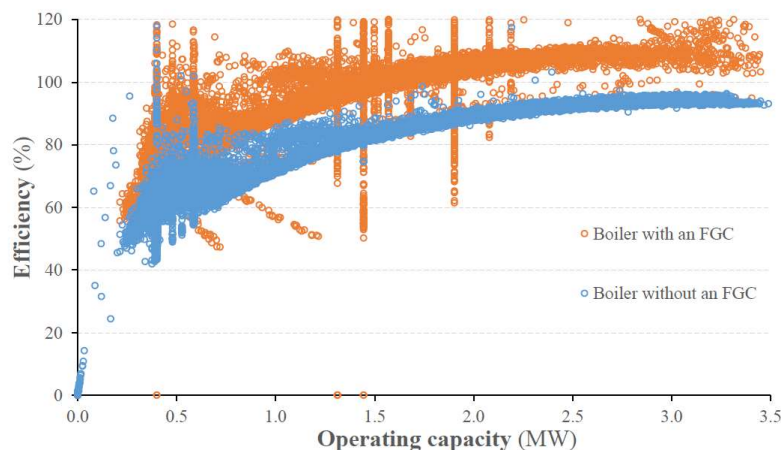
There are two sources of inefficiencies in such district heating system that could be further improved:

- Though the grid losses of Kosta plant are considered low already, low-temperature district heating supply would further reduce the losses. However, the renovation would take some cost as well.
- On the heating user's side, each connected building has varying levels of insulation due to differences in age and the extent of renovations carried out by property owners over time.

### 3.6.3 Measures to improve efficiency

Kosta plant has installed a centrifugal scrubber used as flue gas condenser (FGC). This concept is advantageous especially when coupled with boilers firing wet wood chips in which the heat production efficiency, based on LHV can be increased up to 25% due to the high latent heat of water vapor. The recovered heat serves to preheat the returned district heat water, thus diminishing the need for direct boiler heat production. This enhancement results in higher efficiency of the boiler system, allowing for operation at reduced loads, thanks to the support of the FGC. Such an improvement can significantly transform plant operations, reduce fuel consumption, and increase the potential for electricity cogeneration.

With the installation of the FGC, the boiler efficiency based on the lower heating value of the fuel has been improved by up to 20%. As a result, around 2.3 GWh heat has been recovered during this study period. Taking into account a reduced efficiency of 80% due to the lower operation loads of the boilers, the application of the FGC could lead to a saving of approximately 1500 tons wet wood chips with a moisture content of 45%.



**Figure 3.31: A full year assessed boiler efficiency as a function of operational loads of the biomass boiler in the Kosta district heating plant [18].**

Two potential measures for future considerations:

a) The implementation of low-temperature district heating, either through sub-networks or across the entire network: By adopting low-temperature district heat supply, the return water temperature can be further reduced, maximizing the utilization of recovered heat from the FGC. Additionally, low-temperature district heating would further minimize grid losses, contributing to overall system efficiency improvements.

b) Smart district heating control: Integrating an AI-based prediction model with physics-based models of the district heating network could enable smart control systems that better align supply with consumer demand. This approach would also create opportunities for integrating additional renewable heat sources into the heating grid.

---

## 4 Conclusions and Outlook

---

In summary, the assessment of existing heating infrastructures across the six district heating systems reveals several common patterns and structural themes despite differences in scale and geography. A prominent trend is the increasing role of biomass as a primary fuel in most systems. Four of the six networks (Łomża, Bornholm, Kretinga, and Kosta) now obtain a majority of their heat from biomass sources – in some cases nearly 100% – drastically reducing their reliance on coal and gas. This widespread shift to biomass over the past two decades has been a practical decarbonization step, often enabled by local resources (wood chips, straw) and supported by policy incentives. However, partners acknowledge that biomass is considered a transitional solution rather than the end-state. There is a shared understanding that future low-carbon systems must diversify beyond combustion of even “carbon-neutral” biomass to truly minimize environmental impacts. Thus, while current emissions on paper are low for these biomass-heavy systems the consortium is looking ahead to integrate cleaner technologies in the long term.

Another recurrent theme is the legacy of oversizing and aging infrastructure. Many of the DHS were originally built in earlier decades anticipating higher demands or city growth that did not fully materialize. This has led to situations like Łomża’s, where the network and plant were significantly over-dimensioned relative to actual heat load. Oversizing contributes to unnecessarily high return temperatures and heat losses, as well as inefficiencies in part-load operation. Across the board, partners found that thermo-hydraulic optimization is needed in older networks – for example, by rightsizing substations and pumps, and by lowering supply temperatures. Indeed, temperature reduction is a common goal: several systems have initiated measures to drop their supply and return temperatures to improve efficiency. In Łomża, operational changes have already lowered the peak supply temperature by ~11–24 °C, and on Bornholm a targeted program aims to cut return temperatures from ~45 °C to 35 °C within a few years. These steps will narrow the temperature differential in networks, reduce thermal losses, and make it easier to integrate renewable heat sources that operate at lower temperatures.

Similarly, network heat losses are being addressed everywhere – through pipeline insulation retrofits and network restructuring. Many systems still have portions of old pipelines (often steel pipe in concrete conduits) that are gradually being replaced with modern pre-insulated pipe. For instance, Kretinga has renovated about 57% of its network length so far, yielding measurable loss reductions, and continues to replace the remainder as a priority. Even where losses were already moderate, each operator seeks further improvements because energy not lost is fuel and cost saved.

The assessments also highlight the importance of modernizing control and monitoring. There is a clear trend toward digitalization: from smart meters at end-user premises to advanced SCADA systems and analytic software for network management. Several case studies show that employing data-driven control strategies can unveil operational inefficiencies (such as suboptimal substation settings or peak load management issues) and help reduce them. For example, Łomża’s detailed monitoring identified over 200 substations with poor cooling performance, information that guided targeted retrofits. In Kosta’s case, integration of an AI-based predictive control is being considered to perfectly align production with demand and to incorporate additional renewable inputs. This digital transformation of district heating operations is a unifying theme that promises lower operating costs, better customer service (through quick fault detection), and incremental efficiency gains across all partner systems.

From a structural standpoint, many of the networks share similar retrofit needs. These include: upgrading or repurposing boiler units (especially retiring coal-fired boilers in favour of cleaner options), expanding thermal storage capacity, and improving customer-side installations (like building-level heat exchangers and controls). For example, both Wejherowo and Rostock plan to significantly increase heat storage – Wejherowo as part of its 2050 climate neutrality investments, and Rostock with its recently commissioned 45,000 m<sup>3</sup> tank (2 GWh) that is now in operation. Storage and flexibility assets are becoming standard as

they allow higher renewable penetration and load balancing. Likewise, excess heat recovery and sector coupling are on multiple agendas: Bornholm is investigating use of industrial surplus heat and Power-to-X (power-to-heat via large heat pumps or electrification of boilers) in tandem with offshore wind developments, and Rostock has already added a power-to-heat unit to use renewable electricity surpluses.

These parallel initiatives point to an emerging theme of making district heating a facilitator of broader energy system integration. In terms of conclusions at this stage, the project has identified that all six district heating systems have viable pathways to become low-carbon or climate-neutral, but the strategies will differ. Smaller systems (like Kosta and Kretinga) have largely achieved renewable-based operations and will focus on efficiency optimization and perhaps adding new services to enhance sustainability. Medium systems (Łomża, Wejherowo, Bornholm) are in transition – having reduced coal usage substantially – and will need to complete their coal phase-outs, optimize biomass usage, and likely introduce new renewable sources (solar thermal, geothermal, large heat pumps) in the near future to continue decarbonizing. The largest system, Rostock, faces the most significant transformation – it must replace a major gas CHP and coal-dependent heat supply with alternatives to meet its 2035 climate targets.

Common to all is the recognition that continuous modernization is not only about asset replacement but also about smarter operation and consumer engagement (e.g. incentives for lower return temperatures, energy efficiency programs for buildings). Each system's assessment in this deliverable provides a baseline, and the patterns observed – such as the dominance of biomass and the need for further efficiency retrofits – inform the next steps of the project. Looking forward, the outlook for these district heating networks will be elaborated in the upcoming Deliverable D2.3, which focuses integrating renewable energy sources into the existing systems. Building on the baseline analyses presented here, the project consortium will develop and evaluate detailed transition pathways for each DHS.

The consortium's collaborative approach will continue, allowing partners to learn from one another's scenario results and to identify synergies. In conclusion, all six district heating systems are poised at the threshold of significant upgrades and shifts. This report's cross-cutting findings of common strengths and challenges will guide the consortium as it moves from assessment to action, ensuring that the diverse systems each find a path to sustainable, low-carbon heating in the years to come.

## 5 Bibliography

---

- [1] Amt für Umwelt- und Klimaschutz, energielenker projects GmbH, „Wärmeplan Rostock 2035 für die Hanse- und Universitätsstadt Rostock,“ 2022.
- [2] Stadtwerke Rostock AG, „GuD-Anlage,“ [Online]. Available: <https://www.SWRAG.de/wir-fuer-hier/fuer-die-region/gud-anlage>. [Zugriff am 26 June 2025].
- [3] KNG Kraftwerks- und Netzgesellschaft mbH, „Fernwärme,“ [Online]. Available: <https://kraftwerk-rostock.de/>. [Zugriff am 21 August 2025].
- [4] Hanse- und Universitätsstadt Rostock, „Statistisches Jahrbuch Rostock 2024,“ [Online]. Available: [https://rathaus.rostock.de/media/rostock\\_01.a.4984.de/datei/2024%20Statistisches%20Jahrbuch.pdf](https://rathaus.rostock.de/media/rostock_01.a.4984.de/datei/2024%20Statistisches%20Jahrbuch.pdf). [Zugriff am 1 July 2025].
- [5] Stadtwerke Rostock AG, „Technische Anschlussbedingungen (TAB) für den Anschluss an das Fernwärmenetz, Ausgabe 2020,“ [Online]. Available: [https://www.swrag.de/INTERSHOP/static/WFS/SWR-Portal-Site/-/SWR-Portal/de\\_DE/Veroeffentlichungen/Downloads/Fernwaerme/TAB\\_Download\\_.pdf](https://www.swrag.de/INTERSHOP/static/WFS/SWR-Portal-Site/-/SWR-Portal/de_DE/Veroeffentlichungen/Downloads/Fernwaerme/TAB_Download_.pdf). [Zugriff am 26 June 2025].
- [6] Bundesministerium der Justiz und für Verbraucherschutz, „Verordnung über Allgemeine Bedingungen für die Versorgung mit Fernwärme (AVBFernwärmeV),“ [Online]. Available: [https://www.gesetze-im-internet.de/avbfernw\\_rmev/](https://www.gesetze-im-internet.de/avbfernw_rmev/). [Zugriff am 26 June 2025].
- [7] AGFW, „Der Energieeffizienzverband für Wärme, Kälte und KWK e. V.,“ [Online]. Available: <https://www.agfw-regelwerk.de>. [Zugriff am 26 June 2025].
- [8] DIN Media GmbH, „DIN 4747:2022-08: Fernwärmeanlagen - Sicherheitstechnische Ausrüstung von Unterstationen, Hausstationen und Hausanlagen zum Anschluss an Heizwasser-Fernwärmenetze,“ [Online]. Available: <https://www.dinmedia.de/de/norm/din-4747/346098021>. [Zugriff am 26 June 2025].
- [9] Stadtwerke Rostock AG, „Wärmespeicher geht in den Regelbetrieb,“ [Online]. Available: <https://www.swrag.de/wir-fuer-hier/fuer-die-region/speicher>. [Zugriff am 26 June 2025].
- [10] A. Meyer, „98 Grad heiß: Stadtwerke planen Europas größten Wasserspeicher unterhalb von Rostock,“ 5 November 2025. [Online]. Available: <https://www.ostseezeitung.de/lokales/rostock/stadtwerke-rostock-planen-europas-groessten-wasser-speicher-unter-der-stadt-POJB37N2HBDLFH5TEIUXG2JIOM.html>. [Zugriff am 26 November 2025].
- [11] FfE, „WARAN – Wärme anbinden und netzdienlich nutzen,“ [Online]. Available: <https://www.ffe.de/projekte/waran-waerme-anbinden-und-netzdienlich-nutzen/>. [Zugriff am 26 June 2025].
- [12] BMWK, „Zweiter Förderaufruf zur Weiterentwicklung und Anwendung der Smart-Meter-Gateway-Kommunikationsplattform für die Digitalisierung von Energienetzen (DigENet II),“ [Online]. Available: <https://www.energieforschung.de/de/foerderung/foerderangebote/archiv-foerderangebote/zweiter-foerderaufruf-zur-weiterentwicklung-und-anwendung-der-smart-meter->

- gateway-kommunikationsplattform-fuer-die-digitalisierung-von-energienetzen-digenet-ii. [Zugriff am 27 June 2025].
- [13] Bundesministerium der Justiz und für Verbraucherschutz, „Gesetz über die Elektrizitäts- und Gasversorgung, Energiewirtschaftsgesetz (EnWG),“ [Online]. Available: [https://www.gesetze-im-internet.de/enwg\\_2005/\\_14a.html](https://www.gesetze-im-internet.de/enwg_2005/_14a.html). [Zugriff am 27 June 2025].
- [14] Bundesministerium der Justiz und für Verbraucherschutz, „Gesetz zum Neustart der Digitalisierung der Energiewende (GNDEW),“ [Online]. Available: <https://www.recht.bund.de/bgbl/1/2023/133/VO.html>. [Zugriff am 27 June 2025].
- [15] Bundesministerium der Justiz und für Verbraucherschutz, „Gebäudeenergiegesetz (GEG),“ [Online]. Available: <https://www.gesetze-im-internet.de/geg/>. [Zugriff am 27 June 2025].
- [16] Stadtwerke Rostock AG, „Jahres- und Tätigkeitsabschluss nach EnWG zum Geschäftsjahr 2022,“ [Online]. Available: [https://www.swrag.de/INTERSHOP/static/WFS/SWR-Portal-Site/-/SWR-Portal/de\\_DE/Veroeffentlichungen/Downloads/Jahresabschluesse/Jahresabschluss-2022-SWRAG.pdf](https://www.swrag.de/INTERSHOP/static/WFS/SWR-Portal-Site/-/SWR-Portal/de_DE/Veroeffentlichungen/Downloads/Jahresabschluesse/Jahresabschluss-2022-SWRAG.pdf). [Zugriff am 27 June 2025].
- [17] Stadtwerke Rostock AG, „Berechnung der spezifischen CO<sub>2</sub>-Emissionen der Fernwärme für das Fernwärmenetz Rostock der Stadtwerke Rostock AG,“ [Online]. Available: [https://www.swrag.de/INTERSHOP/static/WFS/SWR-Portal-Site/-/SWR-Portal/de\\_DE/Veroeffentlichungen/Downloads/Fernwaerme/Zerti\\_FW309\\_CO2\\_Rostock\\_Zertifikat\\_2018.pdf](https://www.swrag.de/INTERSHOP/static/WFS/SWR-Portal-Site/-/SWR-Portal/de_DE/Veroeffentlichungen/Downloads/Fernwaerme/Zerti_FW309_CO2_Rostock_Zertifikat_2018.pdf). [Zugriff am 27 June 2025].
- [18] T. Nguyen und L. Lin, „Potentials and effects of electricity cogeneration via ORC integration in small-scale biomass district heating system,“ *Green Energy and Resources*, p. 100113, Volume 3, Issue 1 2025.