



D6.1

Low-grade RES and waste heat transition: Generic Use Cases

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EXECUTIVE SUMMARY

Deliverable 6.1 provides a common reference framework to support the transition of district heating systems towards low-grade renewable energy sources and waste heat. It compiles representative district heating configurations identified across Lithuania, Poland and Slovakia and connects their main characteristics with suitable technical solutions, preliminary implementation considerations and potential financing routes. The deliverable is intended to support replication by district heating operators facing comparable starting conditions.

The analysis covers representative biomass-based systems in Lithuania, coal- and natural-gas-based systems in Poland, and natural-gas-based systems in Slovakia. These configurations illustrate the different scales, generation mixes, operating conditions and baseline performance found across the project countries. The report then assesses the principal low-grade renewable and recovered-heat solutions considered within Low2HighDH: air-, water- and ground-source heat pumps, solar thermal energy and waste-heat recovery. Indicative information on operating temperatures, seasonal performance, costs, emissions and infrastructure requirements is provided to support an initial comparison of alternatives.

The generic use cases bring these elements together through a common screening approach. Starting from the existing generation configuration, network conditions and heat-demand profile, the approach identifies locally available heat sources, assesses their technical compatibility and defines their potential role in a future heat-supply mix. The resulting pathways are not fixed technology assignments, since the preferred solution depends on local resource availability, source temperature and continuity, network temperatures, connection requirements, available space and existing assets. In many cases, the transition will involve hybrid configurations in which renewable or recovered heat supplies baseload or intermediate demand while existing boilers remain available for peaks, backup and security of supply.

The technical guidance is complemented by an overview of grant schemes, concessional financing instruments and relevant financing institutions in the three target countries. Together, the representative configurations, technology catalogue, screening matrix and financing overview provide district heating operators with a structured starting point for identifying and prioritising potential transition pathways. The results are intended for early-stage orientation and replication support and must be followed by site-specific technical, environmental, economic, financial and contractual assessments before investment decisions are taken.

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LIST OF ACRONYMS AND ABBREVIATIONS

CAPEX	Capital Expenditure
CHP	Combined Heat and Power
CO	Confidential, only for members of the consortium
COP	Coefficient of Performance
DEC	Websites, patents, filing, etc.
DEM	Demonstrator
DH	District Heating
EEEF	European Energy Efficiency Fund
EIB	European Investment Bank
EU	European Union
FEnIKS	Fundusze Europejskie na Infrastrukturę, Klimat, Środowisko
GHG	Greenhouse Gas
ILTE	Investicijos į Lietuvos ekonomiką
LCoH	Levelised Cost of Heat
LGRES	Low-Grade Renewable Energy Sources
O	Other
OPEX	Operating Expenditure
PU	Public
R	Report
RES	Renewable Energy Sources
SME	Small and Medium-sized Enterprise
URE	Urząd Regulacji Energetyki
URSO	Regulatory Office for Network Industries
VAT	Value Added Tax
VERT	National Energy Regulatory Council
VLPA	Viešųjų investicijų plėtros agentūra
WP	Work Package

INTRODUCTION

The transition of district heating systems towards low-grade renewable energy sources and waste heat requires solutions that reflect the characteristics of each local system. District heating networks across Europe differ in scale, generation mix, operating temperatures, demand profile and access to local heat sources. As a result, the modernisation pathway for an existing system cannot be defined through a single standard solution but must start from a clear understanding of the current configuration and the resources available in its surroundings.

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Deliverable 6.1 provides a common reference framework to support this initial assessment within the Low2HighDH project. It presents the current district heating context in Lithuania, Poland and Slovakia and describes representative legacy configurations identified in the project countries. These examples cover different starting points, including biomass-, coal- and natural-gas-based systems, and provide the basis for considering how low-grade renewable and recovered heat could be integrated into existing district heating infrastructure.

The deliverable also presents the main LGRES-based solutions considered relevant for district heating applications, including air-, water- and ground-source heat pumps, solar thermal energy and waste-heat recovery. For each technology, the report provides indicative information on operating temperatures, seasonal performance, investment and operating costs, operational emissions and spatial and infrastructure requirements. These values are intended to support preliminary screening and comparison and should not be interpreted as project-specific technical or investment estimates.

Building on the national context, representative systems and technology catalogue, the generic use cases provide practical guidance on the conditions under which each solution may be most suitable. The screening approach considers the existing generation configuration, locally available heat sources, technical compatibility with network temperatures and demand, the potential role of existing assets, and the main issues to be assessed before developing a project-specific solution.

Finally, the deliverable provides an overview of the main grant schemes, concessional financing instruments and financing institutions identified for district heating investments in Lithuania, Poland and Slovakia. This financing information complements the technical guidance and offers an initial reference for project promoters, while recognising that programme availability, eligibility and financing conditions must be verified at the time of project development.

Overall, Deliverable 6.1 is intended as an orientation and replication-support document rather than a feasibility study. It connects representative district heating configurations, available LGRES solutions, generic application guidance and potential financing routes in a single framework. Finally, the objective of this document is to inspire District Heating operators, that while knowing they have to modernise their District Heating System, do not know what LGRES alternatives are in the market.

COMMON LEGACY DH CONFIGURATIONS

This section provides an overview of the national context and the most common configurations of legacy district heating systems identified in the countries covered by the project. For each country, it briefly describes the current district heating landscape and presents one or two representative examples of relevant system configurations.

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LITHUANIA

Lithuanian district heating is already predominantly renewable and biomass-based. According to the 2024 data presented in the chart below, biomass accounts for 73.7% of total heat sales. The figure shows the evolution of heat sales by fuel in Lithuania between 2020 and 2024, providing the national context for the example presented below. Unlike the examples selected for the other project countries, the Lithuanian case focuses on a biomass-based district heating system, as this is the most common configuration in the country and was therefore considered the most relevant for assessing the integration of LGRES.

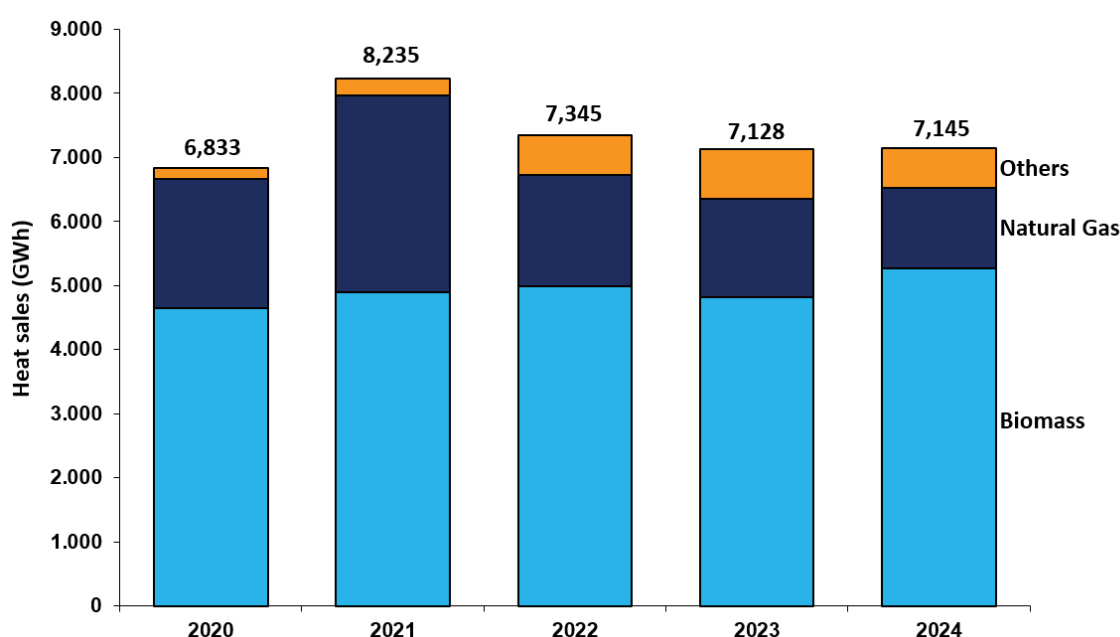


Figure 1. Lithuania: heat sold / supplied by fuel, 2020-2024. VERT

Table 1. Lithuania: 2024 heat sales by fuel and derived shares

Fuel	2024 heat sales	Derived share
Biomass	5,266 GWh	74%
Natural gas	1,262 GWh	18%
Others	617 GWh	9%
Total	7,145 GWh	100.0%

Below the characteristics of a representative Lithuanian DH network are presented, this is a biomass-led configuration, complemented by an absorption heat pump and natural-gas and liquid-fuel reserve capacity.

Table 2. Lithuania representative DH configuration - system size

Configuration	Value
Total length of the pipelines	70 km
Total heated floor area	240,000 m ²

This table identifies the four heat-generation units, the fuel or technology assigned to each unit and their installed thermal capacity, including the reserve and peak-load roles.

Table 3. Lithuania representative DH configuration - heat generation units

	Heat Generation unit 1	Heat Generation unit 2	Heat Generation unit 3	Heat Generation unit 4
Fuel used	Biomass (80-90% of heat demand)	Absorption Heat Pump	Natural gas (Reserve/Peak loads)	Liquid Fuel (Reserve)
Thermal power (MW)	70	5	15	5

This table consolidates the annual fuel and electricity consumption, annual heat production and sales, and the CO₂ emissions reported for the Lithuanian baseline case.

Table 4. Lithuania representative DH configuration - annual fuel consumption, heat output and CO₂ emissions

Parameter	Total
Annual consumption of biomass	65,000 MWh
Annual consumption of natural gas	10,000 MWh
Annual consumption of Liquid Fuel	3,500 MWh
Annual consumption of electricity	1,600 MWh
Annual heat produced	80,000 MWh
Annual heat sold	70,000 MWh
CO ₂ emissions	32,500t

This final baseline table records the current levelized cost of heat for the representative configuration.

Table 5. Lithuania representative DH configuration - current LCoH

	Total
Current LCoH	90 EUR/MWh (VAT incl.)

The configuration allocates 80-90% of heat demand to biomass. The absorption heat pump provides 5 MW, while natural gas (15 MW) and liquid fuel (5 MW) are identified as reserve or peak-load units. The case reports annual heat production of 80,000 MWh, annual heat sales of 70,000 MWh and a LCoH of 9 ct/kWh (VAT incl.).

POLAND

Polish district heating remains dominated by coal. In the 2024 data used for the chart below, coal represents 57.4% of heat supplied, while gaseous fuels and renewable energy sources account for 15.2% and 14.7%, respectively. The consortium therefore presents two representative configurations: one based on coal-fired boilers and one based on natural-gas-fired boilers.

The figure shows the Polish heat supplied by fuel from 2020 to 2024. It highlights the continued weight of coal and provides the context for presenting both coal-fired and natural-gas-fired project examples.

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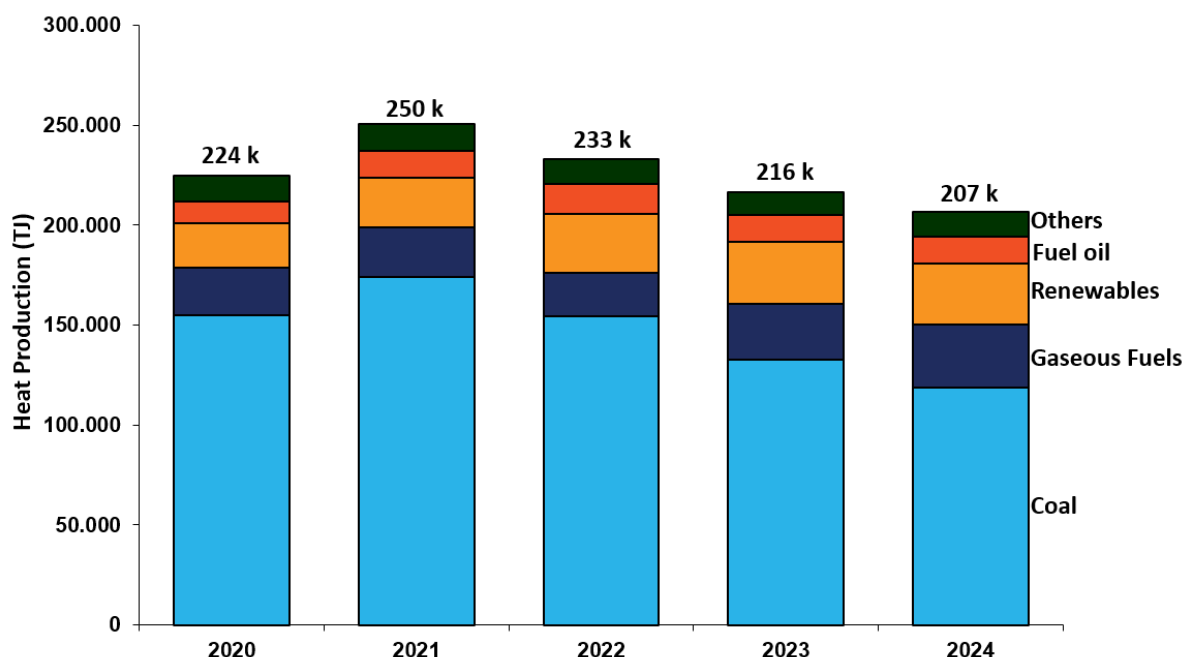


Figure 2. Poland: heat supplied by fuel, 2020-2024. URE

The table presents the 2024 absolute values behind the figure and expresses each fuel as a share of the total. The total row is the sum of the five original fuel categories.

Table 6. Poland: 2024 heat supplied by fuel and derived shares

Fuel	2024 heat supplied	Derived share
Coal-derived fuels	118,721 TJ	57%
Gaseous fuels	31,438TJ	15%
Renewable energy sources	30,404 TJ	15%
Fuel oil	13,651 TJ	7%
Other fuels	12,617 TJ	6%
Total	206,830 TJ	100%

Representative project example 1: coal-fired DH configuration

This table reports the network length and heated floor area defined within the project for the representative Polish coal-fired case.

Table 7. Poland representative coal-fired DH configuration - system size

Configuration	Value
Total length of the pipelines	14 km
Total heated floor area	250,000 m ²

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This table sets out the three coal boilers, the hard-coal fuel used in each unit and the thermal capacity assigned to each boiler.

Table 8. Poland representative coal-fired DH configuration - heat generation units

	Unit 1	Unit 2	Unit3
Type of heat generation unit	Coal boiler	Coal boiler	Coal boiler
Fuel used	Hard coal	Hard coal	Hard coal
Thermal power (MW)	8	5	2

This table brings together the annual coal and electricity consumption, heat produced and sold, and the CO₂ emissions reported for the coal-fired baseline.

Table 9. Poland representative coal-fired DH configuration - annual fuel consumption, heat output and CO₂ emissions

Parameter	Total
Annual consumption of coal	6,600 t/a
Annual consumption of electricity	700 MWh/a
Annual heat produced	129,600 GJ/a
Annual heat sold	112,000 GJ/a
CO ₂ emissions	15,000 tCO ₂ /a

This table records the current levelised cost of heat reported within the project for the Polish coal-fired configuration.

Table 10. Poland representative coal-fired DH configuration - current LCoH

Configuration	Value
Current LCoH	125PLN/GJ

The coal-fired example has 15 MW of total installed thermal capacity. It reports annual heat production of 129,600 GJ/a, annual heat sales of 112,000 GJ/a, CO₂ emissions of 15,000 tCO₂/a and a current LCoH of 125PLN/GJ.

Representative project example 2: natural-gas-fired DH configuration

This table reports the network length and heated floor area defined within the project for the representative Polish natural-gas-fired case.

Table 11. Poland representative natural-gas-fired DH configuration - system size

Configuration	Value
Total length of the pipelines	12 km
Total heated floor area	200,000 m ²

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This table identifies the three gas boilers, confirms natural gas as the fuel for all units and gives their individual thermal capacities.

Table 12. Poland representative natural-gas-fired DH configuration - heat generation units

	Unit 1	Unit 2	Unit3
Type of heat generation unit	Gas boiler	Gas boiler	Gas boiler
Fuel used	Natural gas	Natural gas	Natural gas
Thermal power (MW)	6	4	2

This table consolidates the annual natural-gas and electricity consumption, heat produced and sold, and the CO₂ emissions reported for the gas-fired baseline.

Table 13. Poland representative natural-gas-fired DH configuration - annual fuel consumption, heat output and CO₂ emissions

Parameter	Total
Annual consumption of natural gas	2,850,000 m ³ /a
Annual consumption of electricity	450 MWh/a
Annual heat produced	99,400 GJ/a
Annual heat sold	88,000 GJ/a
CO ₂ emissions	6,200 tCO ₂ /a

This table records the current levelized cost of heat reported within the project for the Polish natural-gas-fired configuration.

Table 14. Poland representative natural-gas-fired DH configuration - current LCoH

Configuration	Total
Current LCoH	145 PLN/GJ

The natural-gas-fired example has 12 MW of total installed thermal capacity. It reports annual heat production of 99,400 GJ/a, annual heat sales of 88,000 GJ/a, CO₂ emissions of 6,200 tCO₂/a and a current LCoH of 145 PLN/GJ.

SLOVAKIA

Natural gas is the largest fuel in Slovak district heating. It represents 58.0% of the 2024 heat supply shown below. The representative project example is a smaller system supplied by three natural-gas-fired boilers.

The figure shows total Slovak heat supply by fuel between 2020 and 2024. It provides the national context for the smaller natural-gas-fired configuration developed within the project.

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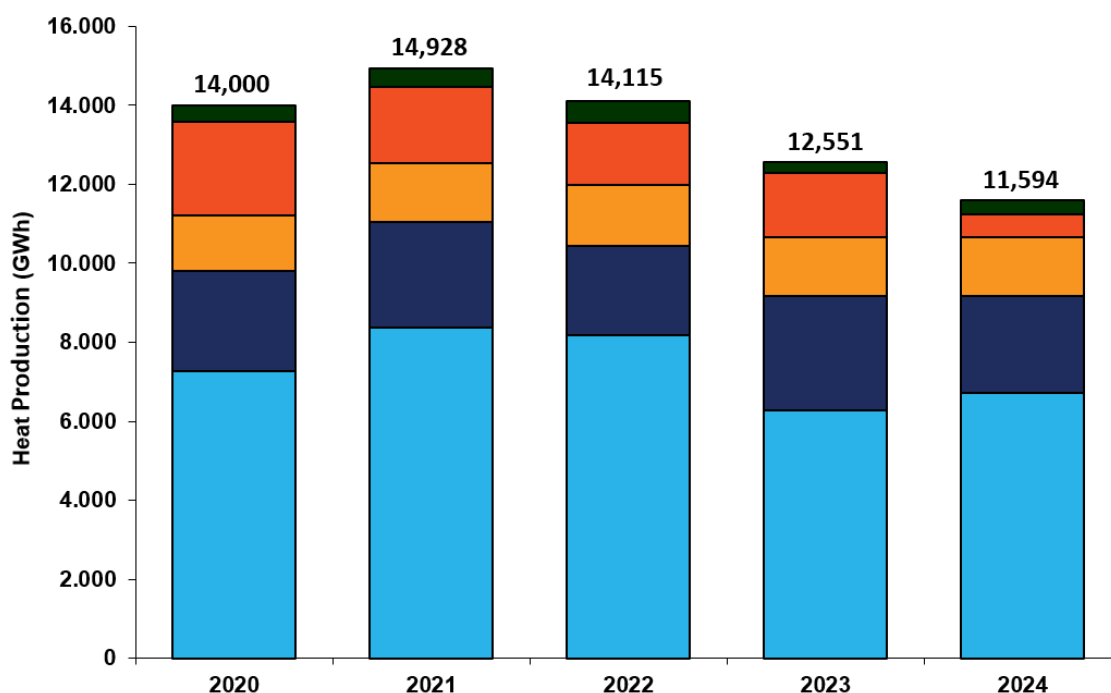


Figure 3. Slovakia: total heat supply by fuel, 2020-2024. URSÓ

The table retains the 2024 absolute heat-supply values used in the figure and converts each fuel category into a percentage of the total.

Table 15. Slovakia: 2024 heat supply by fuel and derived shares

Fuel	2024 heat supply	Derived share
Natural gas	6,724 GWh	58%
Biomass	2,435 GWh	21%
Oil	1,507 GWh	13%
Coal	580 GWh	5%
Biogas	348 GWh	3%
Total	11,594 GWh	100%

Representative project example: natural-gas-fired DH configuration

This table reports the two scale indicators provided for the Slovak example: total pipeline length and total heated floor area.

Table 16. Slovakia representative natural-gas-fired DH configuration - system size

Total length of the pipelines	2 km
Total heated floor area	100 000 m ²

This table identifies the three gas boilers, the common natural-gas fuel and the thermal capacity of each unit.

Table 17. Slovakia representative natural-gas-fired DH configuration - heat generation units

	Unit 1	Unit 2	Unit3
Type of heat generation unit	Gas boiler	Gas boiler	Gas boiler
Fuel used	Natural gas	Natural gas	Natural gas
Thermal power (MW)	3	3	3

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This table consolidates the annual natural-gas and electricity consumption, heat produced and sold, and the CO₂ emissions reported for the Slovak baseline.

Table 18. Slovakia representative natural-gas-fired DH configuration - annual fuel consumption, heat output and CO₂ emissions

	Total
Annual consumption of natural gas	2,200,000 m ³
Annual consumption of electricity	250 MWh
Annual heat produced	21,500 MWh
Annual heat sold	20,400 MWh
CO₂ emissions	5,000 t

This table records the current levelised cost of heat reported within the project for the representative Slovak configuration.

Table 19. Slovakia representative natural-gas-fired DH configuration - current LCoH

	Total
Current LCoH	60 €/MWh

The configuration has 9 MW of total installed thermal capacity. It reports annual heat production of 21,500 MWh, annual heat sales of 20,400 MWh, CO₂ emissions of 5,000 t and a current LCoH of 60 €/MWh.

COMMON LGRES SOLUTIONS

The modernisation of existing district heating systems requires the identification of locally available low-grade renewable energy sources and waste heat, together with the technologies needed to integrate them into the network. The technical suitability of each solution depends not only on the availability and temperature of the heat source, but also on the size of the district heating system, its supply and return temperatures, annual demand profile, existing generation assets and available space.

This section presents the LGRES-based solutions most frequently assessed within the Low2HighDH project: air-, water- and ground-source heat pumps; industrial waste heat; solar thermal energy; and thermal energy storage. Heat pumps are considered separately according to their heat source because source characteristics have a material impact on seasonal efficiency, investment requirements, land use and integration constraints.

The technologies are assessed in relation to the representative district heating configurations presented in the previous section. These comprise coal-fired and natural-gas-fired boiler systems in Poland, a smaller natural-gas-fired system in Slovakia, and a larger biomass-led system in Lithuania. The representative systems range from 9 MW to 15 MW for the fossil-fuelled configurations, while the Lithuanian example includes 70 MW of biomass capacity, a 5 MW absorption heat pump and fossil-fuelled peak and reserve units. This range reflects the different scales and starting points different DH systems have.

For each technology the assessment covers:

- typical operating and output temperature ranges;
- indicative CAPEX and operating costs;
- direct and electricity-related CO₂ emissions; and
- spatial and infrastructure requirements.

The quantitative values presented are intended as indicative screening parameters rather than project-specific investment estimates. Where possible, costs are expressed per unit of installed thermal capacity and emissions per unit of useful heat supplied, allowing solutions to be compared across systems of different sizes. Total investment requirements and actual heat-generation costs will nevertheless depend on the capacity installed in each representative system, the achievable annual operating hours, local electricity prices, the carbon intensity of the electricity supply and the distance between the heat source and the network among other factors.

The solutions should not be interpreted as mutually exclusive. In practice, the most robust modernisation pathways will often combine several technologies. A heat pump may upgrade heat from water, the ground or an industrial process; solar thermal systems may require short-term or seasonal storage; and existing boilers may remain available for peak demand, emergencies or periods when the renewable source is unavailable. Consequently, the following subsections assess both the individual characteristics of each technology and its potential role within a hybrid district heating configuration.

HEAT PUMPS

Heat pumps are a key enabling technology for integrating low-grade renewable heat into district heating systems. Heat pumps use heat available from a lower-temperature source, such as ambient air, water or the ground, and raise it to the temperature required by the district heating network. This allows locally available heat to be supplied to the network using electricity. Electricity is mainly consumed by the compressor, while pumps and fans account for additional auxiliary demand.

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Performance is expressed through the coefficient of performance (COP), defined as useful heat supplied divided by electricity consumed. A COP of 3 therefore means that 1 MWh of electricity delivers approximately 3 MWh of useful heat. The COP decreases as the temperature difference between the heat source and the required network output increases. Seasonal COP values are consequently more representative than design-point values, as they reflect changing source temperatures, network temperatures and part-load operation over the heating season.

Air-, water- and ground-source heat pumps differ mainly in the stability and temperature of the available heat source, as well as in the infrastructure required to access it. The benchmarks below are intended for preliminary technology comparison. CAPEX covers the heat-pump installation and standard balance-of-plant unless noted otherwise. Maintenance OPEX excludes electricity, which is presented separately as the main variable operating-cost component.

Air-source heat pumps

Air-source heat pumps extract heat from ambient air. They are normally the simplest option to deploy because they do not require wells, boreholes or access to a water body. Their main limitation is that efficiency and available thermal capacity decrease during cold periods, when heating demand is typically highest.

Table 20. Main characteristics of air-source heat pumps

Parameter	Indicative benchmark
Typical source and output temperatures	Source temperature follows outdoor conditions. Large-scale units typically supply approximately 60-90 °C; specialised high-temperature units can reach higher temperatures, generally with a lower COP.
Typical seasonal COP	Approximately 2.5-3.5 during the heating season. Performance is strongly affected by winter temperature, defrosting and the required network supply temperature.
Indicative CAPEX	€400-700/kW _{th} for a district-scale installation, excluding major grid reinforcement, thermal storage and extensive integration works.
Maintenance OPEX	Approximately 1.5-2.5% of CAPEX per year, excluding electricity. A central screening benchmark of 2% may be used.
Electricity-related OPEX	Electricity price divided by seasonal COP. At €200/MWh _e , this equals approximately €80/MWh _{th} at COP 2.5, €66.7/MWh _{th} at COP 3 and €57.1/MWh _{th} at COP 3.5.
Operational CO ₂ emissions	No direct combustion emissions. Electricity-related emissions equal the electricity emission factor divided by the seasonal COP, with additional auxiliary consumption where relevant.

Parameter	Indicative benchmark
Spatial and infrastructure requirements	Outdoor evaporator area with unrestricted airflow. Noise and visual impact may require mitigation, while icing and condensation must be managed in cold conditions. Large installations may also require the installation of an electrical transformer.

Water-source heat pumps

Water-source heat pumps recover heat from groundwater, rivers, lakes, seawater, treated wastewater or other suitable water streams. Because water temperatures are generally more stable than ambient-air temperatures, these systems can provide more consistent output and efficiency over the heating season.

Table 21. Main characteristics of water source heat pumps

Parameter	Indicative benchmark
Typical source and output temperatures	Natural or industrial water sources are suitable where stable flow and temperature are available throughout the heating season. As an indicative order of magnitude, extracting 1 MW of heat with a 5 °C water-temperature drop requires approximately 170 m ³ /h of water flow; the actual requirement depends on the heat-pump COP and permitted temperature change. Output temperatures typically range from approximately 60 to 90 °C; specialised or cascaded systems may provide higher temperatures.
Typical seasonal COP	Approximately 3.0-4.5 during the heating season when a stable source is available. Actual performance also reflects abstraction, circulation and treatment energy.
Indicative CAPEX	€500-900/kW _{th} for the heat-pump installation and standard balance-of-plant. Intake, discharge, wells, filtration, pipelines and source-specific civil works may materially increase total CAPEX.
Maintenance OPEX	Approximately 1.5-2.5% of CAPEX per year, excluding electricity. A central screening benchmark of 2% may be used.
Electricity-related OPEX	Electricity price divided by seasonal COP, plus auxiliary electricity for abstraction and circulation. At €200/MWh _e , compressor-related heat cost is approximately €66.7/MWh _{th} at COP 3 and €50/MWh _{th} at COP 4.
Operational CO ₂ emissions	No direct combustion emissions. Electricity-related emissions include compressor demand and auxiliary electricity for source-water pumping, circulation and treatment.
Spatial and infrastructure requirements	Limited plant footprint, but potentially significant source infrastructure, including intake and discharge structures, abstraction or reinjection wells, filtration, intermediate heat exchangers and connection pipelines.

Ground-source heat pumps

Ground-source heat pumps use shallow geothermal energy collected through vertical boreholes or horizontal ground loops. Ground temperature varies less than ambient air temperature, supporting relatively predictable performance. These systems are distinct from medium-depth hydrothermal geothermal resources, which can provide heat at substantially higher source temperatures.

Table 22. Main characteristics of ground-source heat pumps

Parameter	Indicative benchmark
Typical source and output temperatures	Typical shallow-ground source temperatures are approximately 5-10 °C with perforations below 100m. A conventional first-stage heat pump may supply approximately 50-70 °C. Higher network temperatures require a second upgrading stage.
Typical seasonal COP	Approximately 3.5-5.0 for conventional low- to medium-temperature applications. Lower if there are two stages.
Indicative CAPEX	Approximately €600-1,200/kW _{th} including the heat-pump system and ground heat exchanger. For high-temperature (>70-80°C) configurations, indicative equipment costs are €350-400/kW _{th} for the conventional heat-pump stage plus €400-500/kW _{th} for a steam heat-pump stage, excluding the ground field.
Maintenance OPEX	Approximately 2-3% of CAPEX per year, excluding electricity. Around 2% is suitable for a conventional configuration, while 2.5-3% better reflects multi-stage systems.
Electricity-related OPEX	Electricity price divided by the combined seasonal COP. At €200/MWh _e , the heat cost is approximately €52.6/MWh _{th} at COP 3.8, but €80/MWh _{th} where a high-temperature cascade achieves a combined COP of 2.5.
Operational CO ₂ emissions	No direct combustion emissions. Electricity-related emissions depend on the electricity mix and the COP of the complete system; high-temperature cascading increases emissions per unit of useful heat when it lowers the combined COP.
Spatial and infrastructure requirements	Vertical boreholes have limited permanent surface occupation but require drilling access and spacing. Horizontal collectors require substantially more land. Geological investigation, underground pipework and hydraulic connections are required.

Comparison between air-, water- and ground-source heat pumps

The table below summarises the main technical and economic benchmarks for air-, water- and ground-source heat pumps. It provides a high-level comparison of their typical seasonal performance, investment requirements and maintenance costs. The values should be interpreted as indicative ranges for preliminary technology screening, as actual performance and costs will depend on the heat-source conditions, required output temperature, installation scale and site-specific infrastructure.

Table 23. Comparison between air-, water-, and ground-source heat pumps

Heat-pump type	Seasonal COP	CAPEX	Maintenance OPEX
Air-source	2.5-3.5	€400-700/kW _{th}	1.5-2.5% CAPEX/year
Water-source	3.0-4.5	€500-900/kW _{th}	1.5-2.5% CAPEX/year
Ground-source	3.5-5.0	€600-1,200/kW _{th}	2-3% CAPEX/year

SOLAR THERMAL

Solar thermal systems convert solar radiation directly into useful heat by circulating a heat-transfer fluid through a field of solar collectors. The collected heat is transferred to the district heating circuit through a heat exchanger and can either be supplied directly to the network, used to preheat the return flow or stored for later use.

For district heating applications, the most relevant technologies are large-scale flat-plate collectors and evacuated-tube collectors. Flat-plate collectors are generally suited to low- and medium-temperature operation, while evacuated-tube collectors can maintain better performance when higher output temperatures are required. The selection depends primarily on the network temperature, available solar resource, collector efficiency and available installation area.



Figure 4. Flat tube collector (left) and evacuated tube collector (right)

Solar heat production varies with solar irradiation and is generally highest during summer, when district heating demand is lower. Solar thermal systems are therefore normally combined with thermal storage and another generation technology capable of covering demand during periods of insufficient solar availability. Without seasonal storage, solar thermal installations commonly provide only part of the annual heat demand, although they may cover a significant share of the summer load.

Flat plate collectors

Flat-plate collectors use an absorber surface enclosed within an insulated casing. A heat-transfer fluid removes the absorbed solar heat and carries it to the district heating system through a heat exchanger. They are the most established large-scale solar thermal option for low- and medium-temperature district heating, including return-flow preheating and storage charging.

Table 24. Flat plate collectors characteristics

Parameter	Indicative benchmark
Typical output temperature	Approximately 50-90 °C. Performance improves when the required output temperature and the district heating return temperature are relatively low.

Parameter	Indicative benchmark
Indicative CAPEX	Approximately €500-800/kW _{th} , peak for the collector field and standard balance-of-plant. Land, long connection pipelines, major civil works and thermal storage are additional.
Maintenance OPEX	Approximately 1-2% of CAPEX per year, covering inspections, cleaning, pump and valve maintenance, leak detection and periodic heat-transfer-fluid replacement.
Electricity-related OPEX	Mainly circulation pumps and controls. Assuming 0.02 MWh _e per MWh _{th} of heat generated, equivalent to 2% of useful heat, an electricity price of €200/MWh _e results in an auxiliary electricity cost of approximately €4/MWh _{th} .
Operational CO ₂ emissions	No direct combustion emissions. Electricity-related emissions are limited to pumps, controls and auxiliary equipment. At 0.02 MWh _e /MWh _{th} and 200 kgCO ₂ /MWh _e , they equal approximately 4 kgCO ₂ /MWh _{th} .
Spatial and infrastructure requirements	Approximately 1,500-3,000 m ² of collector field per MW _{th} , peak, depending on collector efficiency and layout. Ground-mounted systems also require mounting structures, access, drainage, hydraulic circuits, a heat exchanger and a network connection.

Evacuated-tube collectors

Evacuated-tube collectors place the absorber within an evacuated glass enclosure, reducing convective and conductive heat losses. They can therefore maintain better efficiency than flat-plate collectors at higher operating temperatures or under colder ambient conditions, making them relevant for district heating systems requiring a higher temperature level.

Table 25. Evacuated-tubes collectors characteristics

Parameter	Indicative benchmark
Typical output temperature	Approximately 60-120 °C, depending on collector design, ambient conditions, irradiation and district heating operating temperatures.
Indicative CAPEX	Approximately €700-1,200/kW _{th} , peak, excluding land, long connection pipelines, major civil works and thermal storage.
Maintenance OPEX	Approximately 1.5-2.5% of CAPEX per year. The upper end reflects the greater number and complexity of collector components.
Electricity-related OPEX	Mainly circulation pumps and controls. Assuming 0.02 MWh _e per MWh _{th} of heat generated, equivalent to 2% of useful heat, an electricity price of €200/MWh _e results in an auxiliary electricity cost of approximately €4/MWh _{th} .
Operational CO ₂ emissions	No direct combustion emissions. Indirect operational emissions depend on auxiliary electricity consumption and the applicable electricity emission factor.
Spatial and infrastructure requirements	Broadly comparable collector-field requirements to flat-plate systems, subject to collector efficiency and layout. The installation requires suitable unshaded land or roof area, mounting structures, hydraulic

Parameter	Indicative benchmark
	circuits, heat exchangers and a connection to the district heating network.

WASTE-HEAT

Waste heat refers to thermal energy generated as a by-product of industrial, commercial or infrastructure-related activities that would otherwise be released into the environment. Potential sources include industrial processes, power generation, data centres, wastewater treatment plants, refrigeration systems and other facilities with a continuous or recurring heat surplus.

The suitability of a waste-heat source for district heating is highly site-specific. Its potential depends primarily on the temperature, thermal capacity and availability profile of the source, as well as its distance from the district heating network. The source must also be sufficiently stable over time to justify the infrastructure required for its recovery and transport.

High- and medium-temperature waste heat may be introduced directly into the district heating system through a heat exchanger, provided that its temperature is compatible with the network operating conditions. Lower-temperature sources generally require a heat pump to raise the recovered heat to the temperature needed by the network. Thermal storage may also be used to manage differences between the availability of the waste-heat source and the district heating demand profile.

Unlike other technologies presented in this section, general CAPEX and OPEX benchmarks are not provided for waste-heat recovery. Project costs depend on the characteristics of the source and may include heat exchangers, heat pumps, pumping equipment, thermal storage, source-side adaptations and pipelines connecting the source to the district heating network. In particular, the required connection distance can significantly affect both investment requirements and pumping consumption.

Waste-heat recovery produces no direct combustion emissions at the district heating plant. However, electricity-related emissions may arise from circulation pumps and, where required, heat pumps used to upgrade the source temperature. The resulting operational emissions therefore depend on the electricity consumption of the complete system, the applicable electricity emission factor and the temperature increase required.

The physical footprint of the recovery equipment is generally limited, although additional space may be required for heat exchangers, heat pumps, pumping stations and thermal storage. The most significant infrastructure requirement is often the pipeline connecting the waste-heat source to the district heating network.

Beyond the technical parameters, implementation requires a reliable long-term arrangement between the heat supplier and the waste-heat provider. The assessment should therefore consider the expected continuity of the underlying activity, planned process changes, access conditions, responsibilities for equipment operation and the contractual allocation of supply and investment risks. For these reasons, waste heat must be assessed individually for each potential source rather than through standardised technology benchmarks.

GENRIC USE CASES

The previous sections described representative legacy district heating configurations and the main low-grade renewable energy and waste-heat solutions available for their modernisation. This section brings these two elements together by explaining the conditions under which each solution is most likely to provide a technically credible transition pathway for coal-, natural-gas- and biomass-based district heating systems.

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The use cases follow the screening logic presented below. The assessment starts with the existing heat-generation configuration and its operating parameters, including installed capacity, annual heat demand, network temperatures and the role of existing units in covering baseload, peak demand and reserve capacity. It then identifies the low-grade renewable energy and waste-heat sources available in the surrounding area and assesses their temperature, capacity, availability profile and distance from the network.

The baseline fuel is a useful starting point, but it does not determine the modernisation solution on its own. The same technology may be applicable to coal-, gas- or biomass-based systems where local conditions are suitable. Conversely, a theoretically attractive solution may not be viable if the resource is too distant, intermittent, undersized or incompatible with network temperatures. The use cases should therefore be understood as screening pathways rather than fixed technology assignments.

The transition opportunity matrix summarises this approach. Existing boilers may be progressively displaced from baseload operation while remaining available for peaks, backup or emergencies. Heat pumps can upgrade ambient or recovered heat, solar thermal can reduce summer fuel consumption, geothermal and stable waste-heat sources can provide baseload heat, and thermal storage can coordinate production and demand. In practice, the preferred pathway will often combine more than one technology.

The screening table translates the matrix into a common assessment sequence. The technology-specific use cases that follow apply the same sequence by identifying the conditions that favour each solution, its typical role in the modernised heat-supply mix and the main issues that must be verified before proceeding to project-specific feasibility analysis.

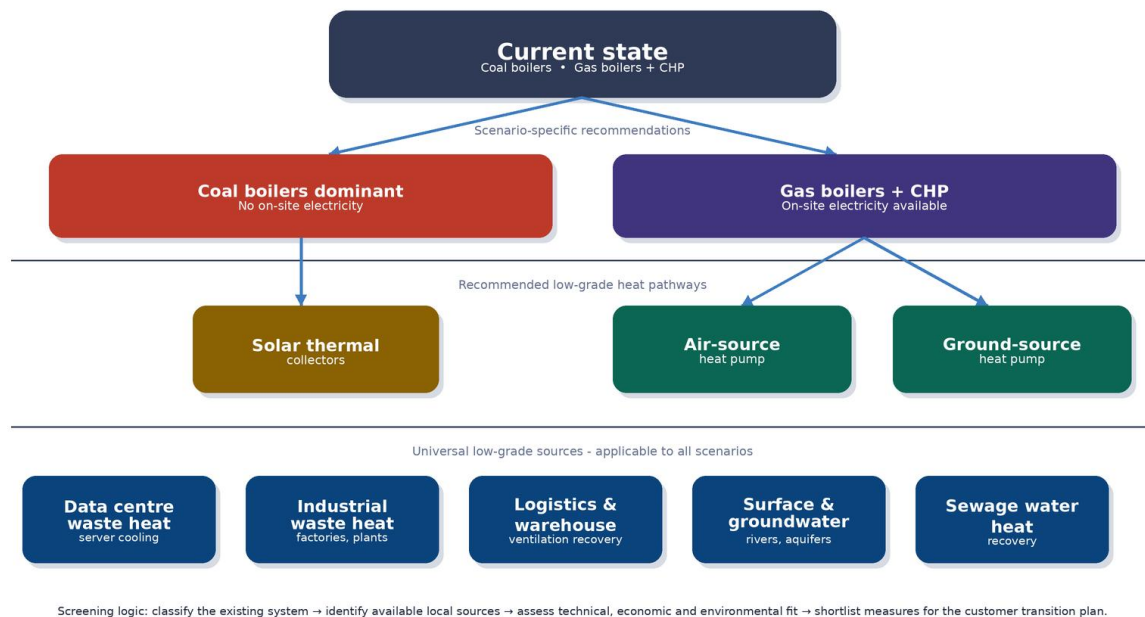


Figure 5. Transition opportunity matrix for identifying low-grade RES and waste heat options in district heating systems

Table 26. Suggested output of the matrix-based screening

Screening element	Main question	Expected output
Current state	What is the dominant fuel and technical configuration?	Baseline category and main operating parameters.
Local sources	Which low-grade RES and waste-heat sources are available nearby?	Shortlist of locally available heat sources and enabling technologies.
Technical fit	Can the option match the network temperature and demand profile?	Preliminary judgement on upgrading, storage, backup and network adaptation.
Contribution to transition	What share of demand and emissions can the option address?	Indicative role in the future heat mix and expected displacement of existing generation.
Implementation plan	What should be investigated first?	Priority data gaps, feasibility tasks and stakeholder actions.

AIR-SOURCE HEAT PUMPS

Air-source heat pumps are the most widely available heat-pump option because ambient air can be used at almost any site and no source wells, boreholes or transmission pipelines are required. They are therefore particularly relevant where the objective is to introduce renewable heat with comparatively limited source-development works.

Their main constraint is that source temperature and thermal output fall during cold periods, when district heating demand is highest. They are consequently most effective in networks with moderate supply temperatures, where they can inject heat into the return line, or in hybrid systems that retain

existing boilers for the coldest hours. Where high network temperatures must be maintained, the larger temperature lift reduces the seasonal COP and increases electricity consumption.

Best suited to:

- Sites without a stable nearby water, geothermal or waste-heat source.
- Smaller or medium-sized networks seeking a modular and relatively straightforward first step.
- Networks able to use moderate-temperature heat or progressively reduce operating temperatures.

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Typical role in the modernised system: Baseload or intermediate-load production, with existing coal, gas or biomass boilers retained for winter peaks and reserve capacity.

Key conditions to verify: Available outdoor area and airflow, winter performance, noise and icing constraints, required electrical connection and the seasonal COP at actual network temperatures.

WATER-SOURCE HEAT PUMPS

Water-source heat pumps are preferred where groundwater, a river, lake, treated-wastewater stream or another sufficiently large water source is located close to the district heating system. Water temperatures are generally more stable than ambient air temperatures, which can support a more consistent seasonal COP and available capacity during the heating season.

This makes water-source systems suitable for covering a substantial share of annual baseload demand. However, the apparent quality of the source must be assessed together with extraction, discharge, filtration and pumping requirements. A distant source or one with limited winter flow may require disproportionate connection infrastructure and auxiliary electricity.

Best suited to:

- Networks close to a stable water body, aquifer or treated-wastewater outlet. As an indicative order of magnitude, extracting 1 MW of heat with a 5 °C water-temperature drop requires approximately 170 m³/h of water flow; the actual requirement depends on the heat-pump COP and permitted temperature change.
- Systems with sufficient annual operating hours to justify intake, discharge and connection works.
- Coal-, gas- or biomass-based plants where boilers can remain available for peaks and contingencies.

Typical role in the modernised system: Predominantly baseload heat production, potentially displacing a large share of annual fuel use while retaining dispatchable generation for peak demand.

Key conditions to verify: Seasonal flow and temperature, water quality, extraction and discharge permits, source-to-network distance, pumping energy and the capacity of the electricity connection.

GROUND-SOURCE HEAT PUMPS

Ground-source heat pumps use a borehole field or horizontal ground collectors to provide a stable low-temperature source throughout the year. They are attractive where predictable seasonal performance is prioritised and sufficient land or subsurface access is available.

The main limitation is the size and cost of the ground heat-exchanger field. District-scale systems can require extensive drilling, while horizontal collectors require substantial land. Ground-source heat

pumps are therefore better suited to smaller networks, new developments, decentralised subnetworks or heating plants with adjacent land. If a high-temperature legacy network requires a second upgrading stage, the combined COP may reduce the value of the otherwise stable source.

Best suited to:

- Sites with suitable geology and adequate land or subsurface access.
- Networks with stable baseload demand and moderate temperature requirements.
- Projects where higher upfront source-development costs can be supported by long operating hours.

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Typical role in the modernised system: Stable baseload or intermediate-load production, generally combined with existing boilers for peak demand.

Key conditions to verify: Geological conditions, borehole spacing and depth, available land, thermal interference, drilling risk and the combined COP where high-temperature upgrading is needed.

SOLAR THERMAL

Solar thermal is best suited to networks with adequate unshaded land or roof area and a relevant summer heat load. Flat-plate collectors are generally favoured for low- and medium-temperature operation, while evacuated-tube collectors may be considered where higher output temperatures are required.

Solar production is variable and seasonally concentrated, so it should normally complement rather than replace dispatchable generation. Its most direct application is to cover part of domestic hot-water demand, preheat the network return flow or reduce summer operation of coal, gas or biomass boilers. Short-term storage improves daily utilisation, while seasonal storage can increase the annual solar contribution but requires substantially more space and investment

Best suited to:

- Networks with stable summer demand and low or moderate return temperatures.
- Sites with sufficient unshaded area close to the network.
- Plants where reducing inefficient summer boiler operation provides operational value.

Typical role in the modernised system: Supplementary renewable production, mainly during summer and shoulder periods, normally combined with storage and dispatchable backup.

Key conditions to verify: Solar irradiation, collector area, shading, connection distance, network return temperature, summer demand and the scale and purpose of thermal storage.

WASTE HEAT

Waste heat should be prioritised where a sufficiently large, stable and accessible surplus-heat source is located close to the district heating network. Relevant sources can include industrial processes, data centres, refrigeration systems, wastewater treatment and other facilities that continuously or periodically reject heat.

Usability depends first on source temperature. Medium- or high-temperature heat may be integrated directly through a heat exchanger, while lower-temperature sources require a heat pump. Availability and distance are equally important: a technically attractive source may not be viable if production is

intermittent, the facility may close, or long transmission pipelines are required. Technical design and the commercial arrangement with the heat provider must therefore be assessed together.

A relevant example is the recovery of heat from mine water. Water pumped from active or abandoned mines can provide a stable, low-temperature heat source, which can be upgraded through a heat pump and supplied to the district heating network. This solution can also support the productive reuse of former mining infrastructure and may be applicable in many mining regions of Poland, as well as in other countries with a significant mining legacy.

Best suited to:

- A stable surplus-heat source with sufficient capacity close to the network.
- Sources whose operating profile overlaps materially with district heating demand.
- Projects where a long-term agreement can allocate availability, investment and operating risks.

Typical role in the modernised system: Direct baseload supply where temperature is sufficient, or heat-pump-assisted baseload supply for lower-temperature sources; storage may manage short-term mismatches.

Key conditions to verify: Measured temperature and capacity, availability profile, connection route, required heat-pump lift, continuity of the source activity and long-term contractual arrangements.

FINANCING

Modernisation can combine the project owner's own or public resources with non-redeemable grants and redeemable finance. Redeemable sources include concessional debt provided by national banks, development banks or EU funds and programmes, as well as non-concessional commercial debt. Programme validity, eligibility criteria and current conditions should be checked at the time of consultation.

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The project diagram summarises the generic with-recourse structure: own project or entity resources are combined with grants and loans, while liability extends to organisational assets beyond project revenues.

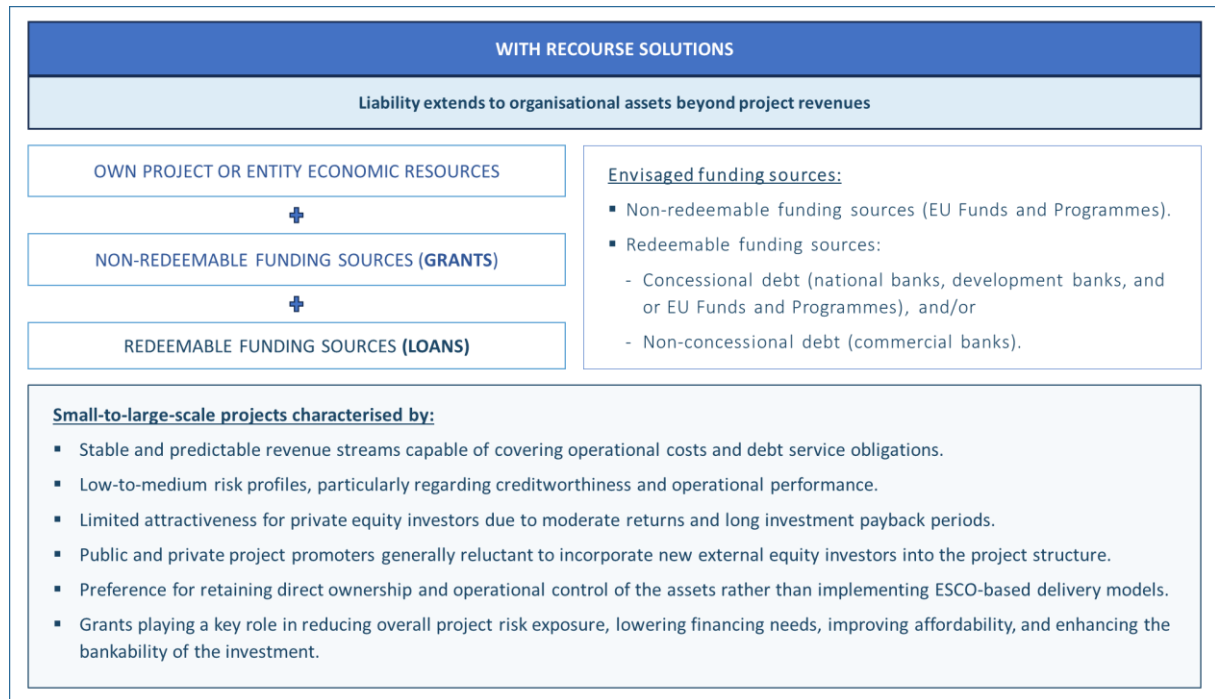


Figure 6. Generic project financing structure with recourse

Lithuania

For Lithuania, the project analysis identifies grant intensities differentiated by enterprise size, regional programmes, EU-supported financing instruments and public development institutions. The following tables reproduce the project information in full.

This table presents the non-redeemable schemes identified for Lithuania and shows how the indicative aid intensity varies by enterprise size or is determined through the applicable regional call.

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Table 27. Summary of indicative grant schemes for DH investments in Lithuania

Grant	Entity size	Indicative grant intensity
Europos Sąjungos fondų investicijų programa (VLPA)	Small enterprise	DH modernisation / energy efficiency investments: Up to 45% of eligible costs.
	Medium enterprise	DH modernisation / energy efficiency investments: Up to 35% of eligible costs.
	Large enterprise	DH modernisation / energy efficiency investments: Up to 25% of eligible costs.
Regionų plėtros programa	To be confirmed by region	Region-specific. To be confirmed under the applicable regional call.

This table lists the EU-supported redeemable instruments identified for Lithuania, together with their indicative project size and financing amount or blending conditions.

Table 28. Summary of indicative EU-supported concessional financing instruments for Lithuania

Programme	Indicative project size	Indicative financing amount
European Energy Efficiency Fund	€5 million to €25 million	Typically €5m–€25m per project, subject to EEEF assessment.
InvestEU	Flexible / project-specific	Determined case-by-case by the implementing partner.
Public Sector Loan Facility	From €25 million (Only for Just Transition Territories)	Blending facility: EIB loans (up to 50% of total investment; min €12.5m). EU grants (15% of the loan amount, or 25% in less developed regions).

This table identifies the multilateral and national institutions considered relevant for Lithuanian DH projects and summarises the typical financing profile stated for each institution.

Table 29. Relevant financing institutions for DH projects in Lithuania

Institution	Institution type	Typical financing profile
European Investment Bank	Multilateral public bank	Typically medium-to-large-scale infrastructure financing. Direct loans generally start at around €25m and frequently exceed €50m for infrastructure projects.
Council of Europe Development Bank	Multilateral development bank	Typically medium-scale public infrastructure and municipal financing. Financing size generally assessed case-by-case.
Nordic Investment Bank	Multilateral development bank	Typically medium-to-large-scale infrastructure and energy transition financing, including district heating and energy efficiency projects. Financing size assessed case-by-case.
Investicijos į Lietuvos ekonomiką (ILTE)	National development financial institution	Typically small-to-medium-scale financing, guarantees and blended finance structures supporting energy efficiency, renewable energy and public-sector investments. Financing size assessed case-by-case.

Poland

For Poland, the consortium analysis identifies grant support from the Modernisation Fund and FENIKS, EU-supported redeemable instruments and financing institutions ranging from multilateral development banks to Bank Gospodarstwa Krajowego. The following tables reproduce the consortium information in full.

This table summarises the two non-redeemable schemes identified for Poland and states the eligible investment focus and indicative support level for each scheme.

Table 30. Summary of indicative grant schemes for DH investments in Poland

Grant	Entity size	Indicative grant intensity
Modernisation Fund	Not specified by company size	RES heat generation for DH: Up to 50% of eligible costs.
FENIKS 2021–2027 - Fundusze Europejskie na Infrastrukturę, Klimat, Środowisko	Not specified by company size	DH network infrastructure: Funding-gap-based support, capped at 79.71% of eligible costs, subject to the applicable methodology and State aid rules.

This table presents the redeemable instruments identified for Poland, including the project-size conditions and the financing amounts or blending terms set out in the project.

Table 31. Summary of indicative EU-supported concessional financing instruments for Poland

Programme	Indicative project size	Indicative financing amount
European Energy Efficiency Fund	€5 million to €25 million	Typically €5m–€25m per project, subject to EEEF assessment.
InvestEU	Flexible / project-specific	Determined case-by-case by the implementing partner.
Modernisation Fund	RES heat generation projects for DH, minimum 2 MWT installed RES thermal capacity	Loan support up to 70% of eligible costs, with a loan amount up to 300m PLN. Where combined with a grant, total support should be checked against the applicable programme cap.
Public Sector Loan Facility	From €25 million (Only for Just Transition Territories)	Blending facility: EIB loans (up to 50% of total investment; min €12.5m). EU grants (15% of the loan amount, or 25% in less developed regions).

This table lists the multilateral and national financing institutions identified for Polish DH projects and describes their typical infrastructure or energy-transition financing profile.

Table 32. Relevant financing institutions for DH projects in Poland

Institution	Institution type	Typical financing profile
European Investment Bank	Multilateral public bank	Typically medium-to-large-scale infrastructure financing. Direct loans generally start at around €25m and frequently exceed €50m for infrastructure projects.
European Bank for Reconstruction and Development	Multilateral development bank	Typically medium-to-large-scale infrastructure financing. DH operations commonly range from ~€5m to above €100m depending on project structure and sovereign backing.
Council of Europe Development Bank	Multilateral development bank	Typically medium-scale public infrastructure and municipal financing. Financing size generally assessed case-by-case.
Bank Gospodarstwa Krajowego	National development bank	Typically medium-to-large-scale public infrastructure, municipal and energy transition financing, including district heating and energy efficiency projects. Financing size assessed case-by-case.

Slovakia

For Slovakia, the project analysis differentiates grant intensities by enterprise size and investment type, and complements these grants with EU-supported redeemable instruments and national promotional institutions. The following tables reproduce the project information in full.

This table presents the Slovak grant schemes by enterprise size and investment category, including the different intensities for RES-based CHP, storage, RES and waste heat, and other efficient DH investments.

Table 33. Summary of indicative grant schemes for DH investments in Slovakia

Grant	Entity size	Indicative grant intensity
Modernisation Fund	Small enterprise	RES-based CHP investments: 65% of eligible costs. CHP-related storage investments: 50% of eligible costs. RES and waste heat investments: 65% of eligible costs. Other efficient DH investments: 50% of eligible costs.
	Medium enterprise	RES-based CHP investments: 55% of eligible costs CHP-related storage investments: 40% of eligible costs RES and waste heat investments: 55% of eligible costs. Other efficient DH investments: 40% of eligible costs.
	Large enterprise	RES-based CHP investments: 45% of eligible costs. CHP-related storage investments: 30% of eligible costs. RES and waste heat investments: 45% of eligible costs. Other efficient DH investments: 30% of eligible costs.
Program Slovensko	Small enterprise located in eligible Just Transition territories	RES-based DH investments (including RES CHP): 65% of eligible costs. Other efficient DH investments: 50% of eligible costs.
	Medium enterprise located in eligible Just Transition territories	RES-based DH investments (including RES CHP): 55% of eligible costs. Other efficient DH investments: 40% of eligible costs.
	Large enterprise located in eligible Just Transition territories	RES-based DH investments (including RES CHP): 45% of eligible costs. Other efficient DH investments: 30% of eligible costs.

This table lists the EU-supported redeemable instruments identified for Slovakia and states the indicative project sizes and financing or blending conditions attached to each programme.

Table 34. Summary of indicative EU-supported concessional financing instruments for Slovakia

Programme	Indicative project size	Indicative financing amount
European Energy Efficiency Fund	€5 million to €25 million	Typically €5m–€25m per project, subject to EEEF assessment.
InvestEU	Flexible / project-specific	Determined case-by-case by the implementing partner.
Public Sector Loan Facility	From €25 million (Only for Just Transition Territories)	Blending facility: EIB loans (up to 50% of total investment; min €12.5m). EU grants (15% of the loan amount, or 25% in less developed regions).

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This table identifies the multilateral and national institutions considered relevant for Slovak DH projects and summarises the financing profile stated for each institution.

Table 35. Relevant financing institutions for DH projects in Slovakia

Institution	Institution type	Typical financing profile
European Investment Bank	Multilateral public bank	Typically medium-to-large-scale infrastructure financing. Direct loans generally start at around €25m and frequently exceed €50m for infrastructure projects.
European Bank for Reconstruction and Development	Multilateral development bank	Typically medium-to-large-scale infrastructure financing. DH operations commonly range from ~€5m to above €100m depending on project structure and sovereign backing.
Council of Europe Development Bank	Multilateral development bank	Typically medium-scale public infrastructure and municipal financing. Financing size generally assessed case-by-case.
Slovenská záručná a rozvojová banka	National development bank	Typically small-to-medium-scale municipal, SME and public-sector financing, generally below large multilateral bank ticket sizes.
Slovak Investment Holding	National promotional financial institution	Typically small-to-medium-scale financing and blended finance structures supported by EU financial instruments, usually below large multilateral infrastructure financing sizes.

CONCLUSIONS

This deliverable provides a structured reference framework for understanding the current district heating context in Lithuania, Poland and Slovakia and for identifying the low-grade renewable energy and waste-heat solutions that may support the modernisation of existing systems. The national overviews and representative configurations illustrate the diversity of starting points across the project countries, from coal- and natural-gas-based systems to a predominantly biomass-based district heating sector.

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The technology catalogue presents the main characteristics of air-, water- and ground-source heat pumps, solar thermal energy and waste-heat recovery. The indicative information on operating temperatures, seasonal performance, costs, emissions and infrastructure requirements is intended to support initial technology screening and comparison. It does not constitute a project-specific technical or economic assessment, as actual performance and investment requirements depend on local resource conditions, network temperatures, system scale, operating hours and the infrastructure required for integration.

The generic use cases translate this information into practical guidance on when each solution may be most relevant. The appropriate pathway is not determined solely by the fuel currently used, but also by the availability, temperature, capacity and continuity of local heat sources, their distance from the network, the district heating demand profile and the role of existing generation assets. In many cases, a hybrid configuration may be appropriate, with renewable or recovered heat covering part of the demand and existing units retained for peak loads, backup or security of supply.

The financing overview complements the technical guidance by presenting the main categories of grants, concessional instruments and financing institutions identified for district heating investments in the three countries. These financing options provide an initial reference for project promoters, although eligibility, programme availability and financing conditions must be verified for each project at the time of application.

Overall, Deliverable 6.1 provides district heating operators and other relevant stakeholders with a common starting point for identifying potential LGRES-based transition pathways and the financing routes that may support them. Its purpose is to facilitate early-stage orientation and prioritisation, while recognising that any selected pathway must subsequently be validated through site-specific technical, environmental, economic, financial and contractual assessments.

The framework and guidance developed in this deliverable will be used as a basis for Deliverable 6.4, the Local Replication Roadmap. In line with the Grant Agreement, Deliverable 6.4 will build on this generic technical and financing framework to provide guidance on evaluating technological feasibility, developing a financial plan and engaging the local stakeholder community when replicating Low2HighDH solutions in other district heating contexts.