



## D6.4

### Local Replication Roadmap

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| <b>Lead Authors</b>                   | Pedro Porto Mato                                                                             |
| <b>Contributors</b>                   | Pablo Baigorria Kobylinski                                                                   |
| <b>Submitted by</b>                   | David Pérez (Creara)                                                                         |
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| Nature of the deliverable |                                 |   |
|---------------------------|---------------------------------|---|
| <b>R</b>                  | Report                          | x |
| <b>DEC</b>                | Websites, patents, filing, etc. |   |
| <b>DEM</b>                | Demonstrator                    |   |
| <b>O</b>                  | Other                           |   |

| Dissemination level |                                                                                      |   |
|---------------------|--------------------------------------------------------------------------------------|---|
| <b>PU</b>           | Public                                                                               | x |
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## EXECUTIVE SUMMARY

Deliverable 6.4 provides a practical Local Replication Roadmap that translates the Low2HighDH approach into a structured process for integrating low-grade renewable energy sources and waste heat into existing district heating systems and developing technically feasible and financially viable projects with a clear pathway towards implementation.

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The roadmap is structured around three main stages and provides practical guidance on the activities to be undertaken and the outputs to be produced at each stage.

The first stage explains how to define the case study. This includes establishing the project boundaries, characterising the existing district heating system, forecasting future heat production and demand, and identifying the relevant stakeholders and regulatory conditions. It also describes how a Local Liaison Group can support coordination, allocate responsibilities and involve the actors with an interest in or influence over project implementation. Together, these activities establish the baseline for the subsequent technical and financial assessments.

The second stage provides guidance on evaluating technical feasibility. It describes how to identify locally available low-grade renewable energy and waste heat sources, assess their compatibility with the existing network and identify suitable technologies and develop technically feasible scenarios. It also explains how to compare alternative technical scenarios based on their ability to meet future heat demand, their available capacity, their integration with existing assets, their contribution to security of supply, and their use of renewable energy and recovered heat. The result is a shortlist of technically feasible scenarios for subsequent financial assessment.

The third stage sets out the process for assessing the financial viability of the technically feasible scenarios. It explains how to estimate revenues, CAPEX, OPEX and avoided costs, and how to compare the scenarios using financial indicators and sensitivity analysis. It also provides guidance on defining an indicative financing structure combining grants, debt and own resources, while recognising grants as a complementary instrument and highlighting the need to mobilise private capital. This assessment supports the identification of the preferred replication scenario and the definition of its indicative financing structure.

The Rogoźno project is used throughout the roadmap to illustrate how the methodology can be applied in practice. It illustrates the importance of evaluating the complete system configuration and considering technical performance, financial returns, regulatory compliance and long-term decarbonisation objectives together. This case study is used with the project's explicit consent and serves as a practical example of how the methodology can be applied in a real-world context.

Overall, Deliverable 6.4 provides district heating operators, local authorities, utilities and project developers with a common step-by-step methodology for moving from an initial decarbonisation opportunity to a technically and financially assessed replication scenario. The roadmap does not prescribe a standard technology or financing solution, as the preferred pathway must be adapted to local resources, network conditions, demand patterns, regulatory requirements and financing opportunities. Its purpose is to support consistent decision-making and facilitate the development of technically sound, financially credible district heating projects with a clear pathway towards implementation.

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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               |
| CO <sub>2</sub> | Carbon Dioxide                                                 |
| COP             | Coefficient of Performance                                     |
| DCF             | Discounted Cash Flow                                           |
| DEC             | Websites, patents, filing, etc.                                |
| DEM             | Demonstrator                                                   |
| DH              | District Heating                                               |
| DPBT            | Discounted Payback Time                                        |
| EBITDA          | Earnings Before Interest, Taxes, Depreciation and Amortisation |
| ETS             | Emissions Trading System                                       |
| EU              | European Union                                                 |
| FCFF            | Free Cash Flow to Firm                                         |
| HDD             | Heating Degree Days                                            |
| IRR             | Internal Rate of Return                                        |
| LGRES           | Low-Grade Renewable Energy Sources                             |
| LIFE            | Programme for Environment and Climate Action                   |
| MWe             | Megawatt electrical                                            |
| MWt             | Megawatt thermal                                               |
| NPV             | Net Present Value                                              |
| NPVR            | Net Present Value Ratio                                        |
| O               | Other                                                          |
| OPEX            | Operating Expenditure                                          |
| PU              | Public                                                         |
| R               | Report                                                         |
| RES             | Renewable Energy Sources                                       |
| SPBT            | Simple Payback Time                                            |
| WACC            | Weighted Average Cost of Capital                               |
| WP              | Work Package                                                   |

## INTRODUCTION

This Local Replication Roadmap provides a structured methodology to support cities, district heating operators, energy utilities and project developers in assessing the replication potential of Low2HighDH solutions in existing district heating systems.

The roadmap guides users through a step-by-step process covering system definition, technical feasibility assessment and financial evaluation. Its purpose is to facilitate decision making and support the identification of technically feasible and financially viable pathways for district heating decarbonisation.

This roadmap is intended for stakeholders involved in the planning, development and financing of district heating modernisation projects, including:

- Local and regional authorities
- District heating owners and operators
- Energy utilities and infrastructure developers
- Technical experts
- Financial institutions and investors

The methodology can be applied to a wide range of district heating systems and can be adapted to local technical, regulatory and market conditions.

The roadmap is structured into three stages with the purpose of transforming an initial project concept into a technically and financially assessed replication scenario that can support investment and implementation planning.

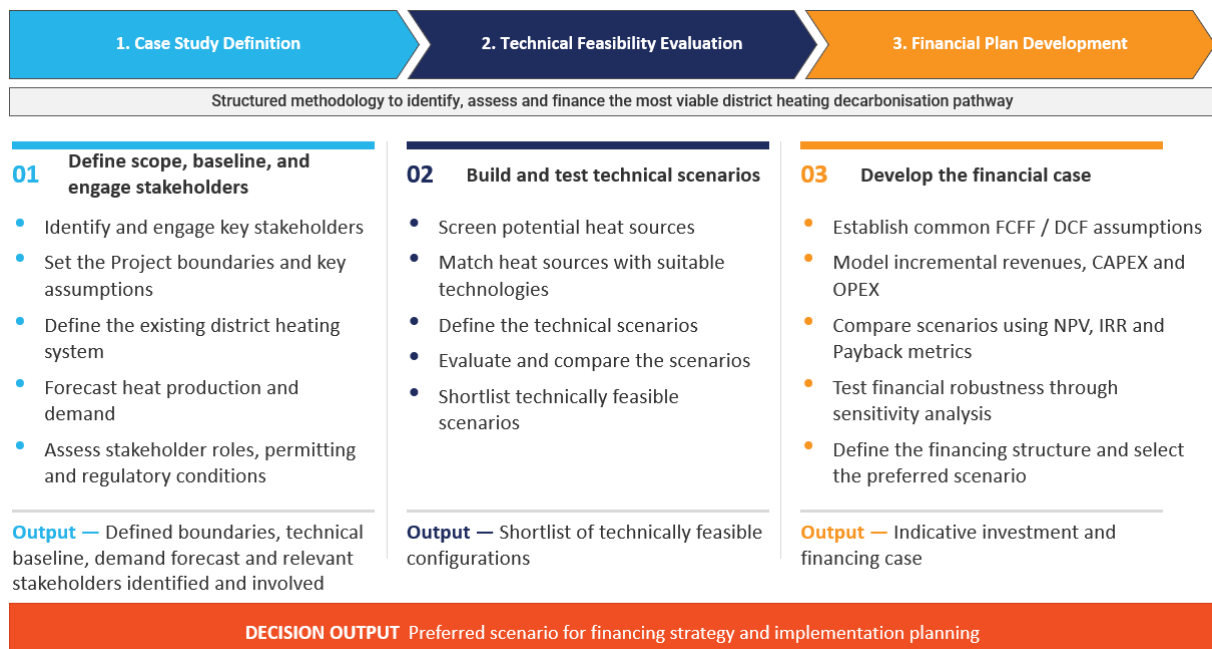


Figure 1: Summary of the pathway of the Local Replication Roadmap

- **Stage 1. Case Study Definition:** Establish the project boundaries, characterise the existing district heating system, define key assumptions, analyse heat demand and identify the relevant stakeholder and regulatory context.
- **Stage 2. Technical Feasibility Evaluation:** Identify potential heat sources and suitable technologies, develop technical scenarios, compare alternative configurations and identify and compare technically feasible scenarios for subsequent financial assessment.
- **Stage 3. Financial Plan Development:** Assess revenues, costs and investment requirements, develop the financial model, compare the financial performance of the technically feasible scenarios and define an indicative financing structure for the preferred scenario.

The outcome of the process is a preferred replication scenario supported by technical and financial assessment, which can inform investment decisions and implementation planning.

To illustrate the practical application of the methodology, each stage includes a simplified example based on the Rogoźno project, a real case analysed within Low2HighDH. The first stage illustrates the definition of the existing system and its heat demand; the second presents the integration of heat recovered from treated wastewater through heat pumps and the comparison of alternative technical configurations; and the third illustrates the financial assessment and indicative financing structure. The case study shows how an otherwise untapped low-temperature heat source can contribute to decarbonising a conventional district heating system operating at relatively high temperatures.

## CASE STUDY DEFINITION

As further detailed in D6.6, before starting the assessment, the promoter should define the purpose and current maturity stage of the project, the decision that the roadmap is expected to support and the next decision gate. Based on this initial definition, the first stage establishes the scope, boundaries and key assumptions of the case study and develops a clear understanding of the existing district heating system.

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The case study should begin by defining the following elements:

- **Geographical scope:** definition of the area covered by the assessment, including the district heating network boundaries and the main supply and demand points
- **Potential heat sources:** identification of the renewable or waste heat sources to be assessed, including their location, estimated potential, and proximity to the district heating network
- **Time horizon:** definition of the assessment period, considering the expected lifetime of the assets, investment planning requirements, and long-term decarbonisation objectives
- **Key assumptions:** main technical, operational and economic assumptions to be applied consistently when developing and comparing the alternative scenarios.

The level of detail of the assessment should be proportionate to the project's maturity and the decision to be supported. At an early stage, the roadmap may support the screening and shortlisting of technically feasible scenarios. For more mature projects, it may support the refinement of technical parameters, financial assumptions and an indicative financing structure. The resulting outputs should therefore be interpreted in relation to the project stage and should not automatically be considered ready to implement or to support financing and implementation decisions.

Once these elements have been defined, the existing district heating system, future heat demand and production requirements, and stakeholder and regulatory context should be characterised.

### DEFINITION OF THE DISTRICT HEATING SYSTEM

In line with the data collection approach set out in D6.6, before developing the technical baseline, the promoter should appoint technical and financial data owners, agree a consolidated data checklist and verify the completeness, format and internal validation of the available information. Any material gaps should be recorded together with their implications for the assessment.

At the start of the process, a joint meeting involving the relevant technical, financial and decision-making representatives should confirm the information required, internal responsibilities, validation arrangements and deadlines.

Once this information has been collected and validated, the existing district heating system should be characterised to establish its technical baseline and assess its readiness to integrate renewable and waste heat sources. The assessment should include:

- **DH operator profile:** ownership structure, operational responsibilities and management model
- **Installed generation capacity:** existing heat production units, nominal capacities and role within the current generation mix
- **Heat generation systems:** fuel types, efficiencies, operating conditions, age and technical condition of the existing equipment

- **Network characteristics and system performance:** network configuration, supply and return temperatures, operating regime, seasonal variations, annual heat production, network losses and overall efficiency
- **Future needs and constraints:** expected regulatory requirements, decarbonisation targets, asset replacement needs and other relevant operational constraints

The network temperature diagram is a standard element of the technical baseline and represents the relationship between supply and return temperatures and outdoor conditions. It supports the characterisation of the network's operating regime and the subsequent assessment of its compatibility with alternative heat sources and integration technologies. The figure below illustrates this standard output using the Rogoźno case.

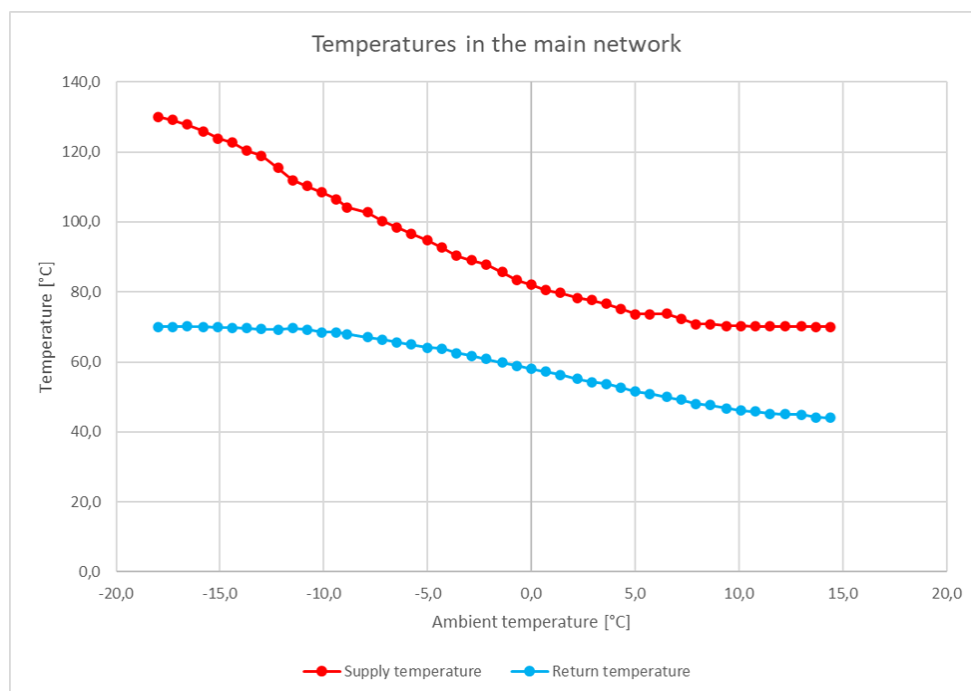


Figure 2: Network supply and return temperatures

The output of this step is a technical baseline describing the existing generation assets, network operating conditions, system performance, demand characteristics, future constraints and initial readiness to integrate alternative heat sources.

## HEAT PRODUCTION AND DEMAND FORECAST

The next step is to develop the heat demand and production requirements forecast. The objective is to estimate the future heat demand of the district heating system and determine the heat production required to meet it over the project lifetime. The forecast should be developed through the following steps:

- **Collect historical operational data:** contracted capacity, heat production, heat sales, heat consumption, and other relevant operational indicators

- **Analyse historical trends:** changes in heat demand and production, network efficiency, heat losses and seasonal demand variations
- **Assess climatic conditions:** historical Heating Degree Days (HDDs), heating-season duration, peak winter temperatures and interannual weather variability. HDDs provide a consistent indicator of heating requirements and allow heat demand to be compared across years with different weather conditions
- **Weather-Normalise Historical Heat Demand:** adjust historical demand using HDDs to separate weather-driven variations from underlying demand trends and enable consistent year-on-year comparisons
- **Develop Heat Demand Profiles:** determine seasonal demand patterns, peak demand periods and base-load requirements
- **Assess Future Demand Drivers:** evaluate how building renovation and energy-efficiency improvements may reduce heat consumption, how climate change and milder winters may lower heating needs, and how network expansion or changes in the number and type of connected consumers may affect future heat demand
- **Develop the Baseline Reference Demand Forecast:** estimate annual heat demand, peak thermal capacity, the expected demand profile and the heat production required to cover demand and network losses over the project lifetime

The annual heat demand profile and the thermal power duration curve are standard elements of the demand forecast. The annual profile represents the chronological evolution of heat demand and supports the identification of seasonal patterns and periods of peak and low consumption. The figure below illustrates this standard output using the Rogoźno case.

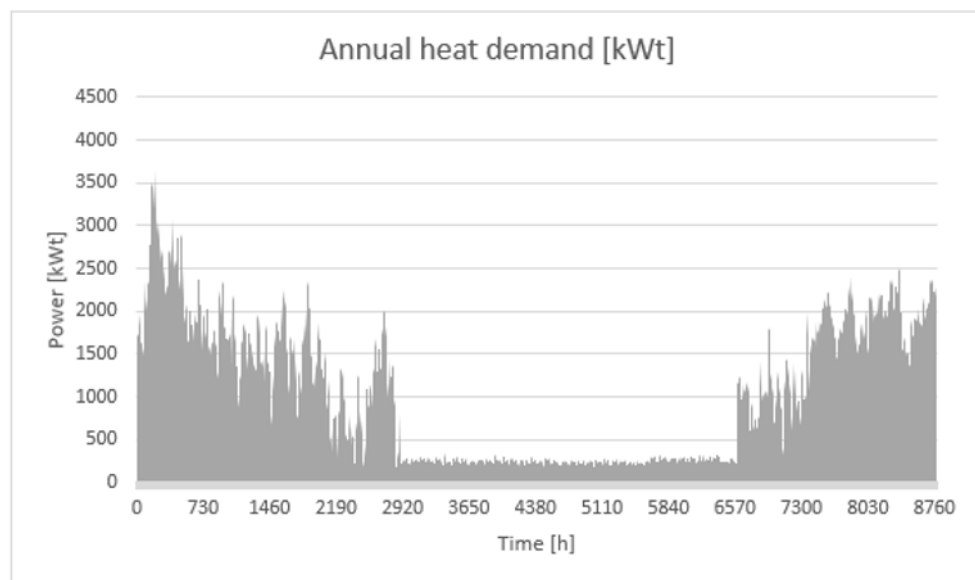


Figure 3: Annual heat demand profile

The thermal power duration curve ranks thermal demand from highest to lowest, supporting the identification of base-load, intermediate-load and peak-load requirements and the preliminary sizing of heat generation technologies. The figure below illustrates this standard output using the Rogoźno case.

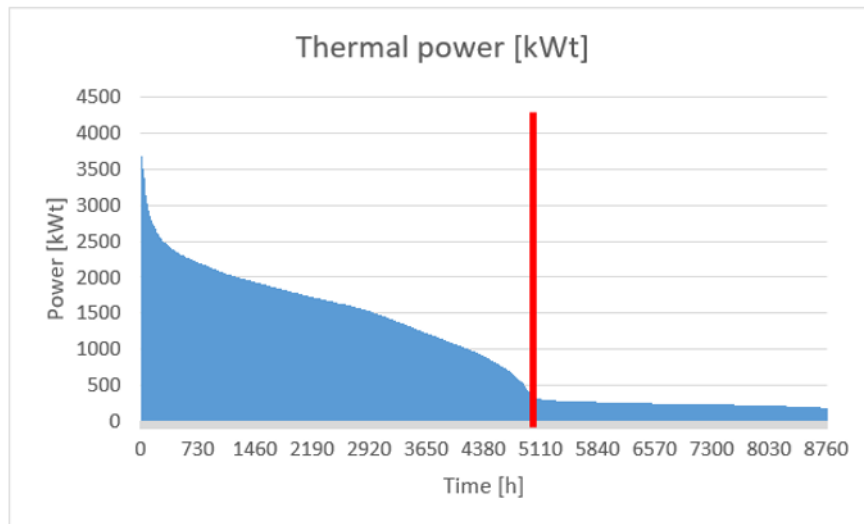


Figure 4: Thermal power duration curve

These two outputs provide complementary representations of the same demand dataset. The annual profile preserves the chronological sequence of demand, while the duration curve shows how frequently each thermal load level occurs.

The output of this step is a documented heat demand forecast and the corresponding heat production requirements over the project lifetime. The forecast should be realistic, traceable to the available data and consistent with the climatic, operational and demand assumptions applied.

#### STAKEHOLDER AND REGULATORY CONTEXT

The case study should identify the stakeholders involved in the development, implementation and operation of the project. Depending on the project context and the configurations to be assessed, these may include:

- District heating system owner and operator
- Owner or provider of the renewable or waste heat source
- Heat consumers
- Electricity supplier and grid operator
- Local authorities and regulatory bodies
- Technology providers, contractors and financing institutions

The identified stakeholders should be brought together in a Local Liaison Group to coordinate decisions, monitor progress and address potential barriers. The Local Liaison Group should involve the stakeholders capable of accelerating or delaying the project, giving them a meaningful role in decision-making and clearly defined responsibilities. This shared ownership helps align interests, strengthen commitment, reduce implementation risks and increase the likelihood of project success. As the project advances, the Local Liaison Group should support the coordination of subsequent activities, while formal responsibilities remain with the relevant project owners and implementing entities.

The effective engagement and collaboration of these stakeholders is particularly important, as the successful completion of this step provides the foundation for the technical, financial and implementation activities that follow.

Where heat is supplied by a third party, the technical assessment should be coordinated with the development of the contractual framework. The agreement should address, at least, ownership of the connection assets, heat availability and quality requirements, measurement and verification, supply interruptions, data sharing, liability, duration, renewal and termination conditions. Long-term access to the heat source should also be secured, as project viability may depend on the continued operation of the heat provider.

The applicable regulatory framework should be reviewed from the beginning of the case study. The review should cover:

- Requirements for connecting the new source to the district heating network
- Heat tariff calculation and approval rules
- Conditions applicable to the purchase and sale of heat
- Permitting and environmental requirements
- Rules affecting the use of renewable energy and waste heat
- Criteria for efficient district heating and cooling systems
- Eligibility conditions for grants and other financing instruments

The regulatory assessment should be tailored to the project location and configuration rather than applying a uniform checklist. It should identify the permits and approvals required, the competent authorities, expected timelines, dependencies between procedures and the implications of potential delays for the investment schedule and financing plan.

Regulatory requirements should be assessed together with the technical and financial conditions of the project. Each proposed scenario should be compatible not only with the technical requirements of the system, but also with the applicable tariff, permitting and regulatory framework. As these requirements vary by country and may change over time, they should be verified for the project location and expected implementation date.

The output of this step is a stakeholder and regulatory framework identifying the relevant stakeholders and their responsibilities, establishing the Local Liaison Group's governance structure, and defining the applicable regulatory, permitting, contractual and tariff requirements. It should ensure that the stakeholders with the capacity to support or influence the project are identified and involved from an early stage.

## TECHNICAL FEASIBILITY EVALUATION

Since there is no single pathway for district heating decarbonisation, multiple technical solutions may be suitable for a given system. The purpose of the technical feasibility evaluation is therefore to identify and compare alternative configurations capable of meeting local heat demand while increasing the share of renewable and recovered heat. Rather than assessing individual technologies in isolation, the analysis should consider integrated technical scenarios combining complementary solutions and existing assets where appropriate.

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This roadmap focuses on low-grade renewable energy sources (LGRES) and waste heat because their potential remains largely untapped in existing high-temperature district heating systems. While mature renewable solutions such as biomass are already widely deployed, significant quantities of low-grade heat are available from sources including wastewater, surface water, ambient heat, shallow geothermal energy, mine water and industrial or urban waste heat. These resources are often locally available and can contribute substantially to district heating decarbonisation. However, their lower temperature means they generally cannot be used directly in conventional district heating networks and require specific integration solutions, particularly heat pumps, to upgrade the heat to the temperatures required by the system.

The focus on LGRES does not imply that other renewable technologies, such as biomass, are not relevant for district heating decarbonisation. These technologies may remain part of the existing or future generation mix and can complement LGRES by covering peak loads, providing backup capacity or supplying higher-temperature heat where required. However, this roadmap specifically addresses the technical, financial and organisational challenges associated with unlocking low-grade renewable and recovered heat sources through their integration into existing district heating systems, in line with the objectives and scope of the Low2HighDH project.

The assessment should start with a baseline scenario representing the current configuration of the district heating system. Alternative and hybrid scenarios can then be developed and compared according to their technical performance, integration requirements and operational characteristics. The objective is to identify the most technically feasible configurations for subsequent financial assessment.

To support a structured and replicable evaluation process, the technical feasibility assessment should be carried out following the steps described below.

### TECHNICAL ASSESSMENT METHODOLOGY

The technical feasibility evaluation identifies the technical scenarios that can be integrated into the existing district heating system and carried forward for financial assessment. The evaluation should be completed through the following steps:

- **Screen potential heat sources:** Identify the renewable and waste heat sources available within the area of interest. Potential sources may include wastewater, surface water, groundwater, hot mine water, geothermal resources, industrial excess heat, data centres and other locally available low-grade renewable or recovered heat sources. Each source should be assessed according to its location, distance from the district heating network, available temperature, estimated heat potential, seasonal and long-term availability, reliability of supply, dependence on third parties, infrastructure requirements and relevant technical or environmental constraints. The objective is to exclude clearly unfeasible options and shortlist the most promising heat sources for further assessment.

- **Match heat sources with suitable technologies:** For each shortlisted heat source, assess its compatibility with the district heating system, considering the source temperature, required network temperatures, electricity requirements, connection needs, integration with existing assets and space availability. The assessment should determine whether heat pumps, heat exchangers, thermal storage systems, new pipelines or backup generation assets are required to integrate the source and ensure reliable operation.
- **Define the technical scenarios:** Based on the shortlisted source-technology combinations, develop a series of technical scenarios for further evaluation. A baseline scenario representing the continuation of the existing system should be established as the reference case. Alternative scenarios should consider renewable and waste heat solutions, either as standalone options or combined with existing generation assets. For each scenario, clearly define the technologies included, their role within the heat-supply system and their expected contribution to meeting heat demand.
- **Perform preliminary sizing:** Carry out a preliminary sizing exercise for each technical scenario to estimate the main design parameters and infrastructure requirements. The assessment should be based on the heat demand and production requirements forecast developed previously and should estimate installed capacity, annual heat production, operating hours, base-load and peak-load contribution, backup capacity and storage needs, where applicable. The sizing should provide a sufficient basis for comparing scenarios and should not be interpreted as detailed engineering design.
- **Evaluate and compare the scenarios:** Evaluate the technical scenarios using a common set of criteria to ensure consistent comparison. The assessment should consider their ability to meet annual and peak heat demand, compatibility with network operating conditions, operational reliability, security of supply, renewable and recovered heat contribution, potential emissions reduction, infrastructure complexity, land requirements, dependence on external resources and future expansion potential. The results should be summarised in a comparison matrix highlighting the main advantages, constraints and critical assumptions associated with each scenario.

The output of this step is a shortlist of technically feasible scenarios, supported by preliminary sizing and a consistent comparison of their technical performance, integration requirements, main constraints and critical assumptions. These scenarios provide the basis for technology selection and subsequent financial assessment. This output can be presented in a technical scenario diagram providing a structured representation of the alternative system configurations considered. The figure below presents this standard output for the Rogoźno case.

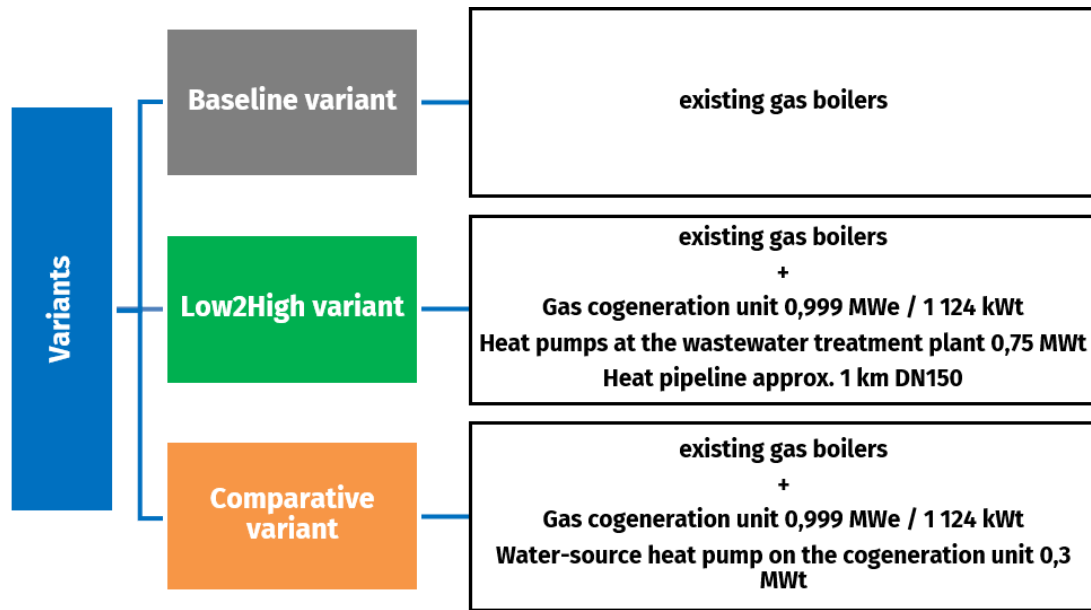


Figure 5: Variant analysis of the Rogoźno project

#### TECHNOLOGY SELECTION

Technology selection should be based on the characteristics of the existing district heating system, the availability and characteristics of local heat sources, and the role that each technology can perform within the overall system configuration. Technologies should not be assessed in isolation, as district heating decarbonisation pathways may combine several complementary solutions while retaining existing generation assets to cover peak demand, provide backup capacity or respond to emergencies.

The following diagram presents an indicative decision-making process for identifying suitable technologies according to the characteristics of the existing system and locally available resources. The process should be adapted to the specific technical, operational and spatial conditions of each project.

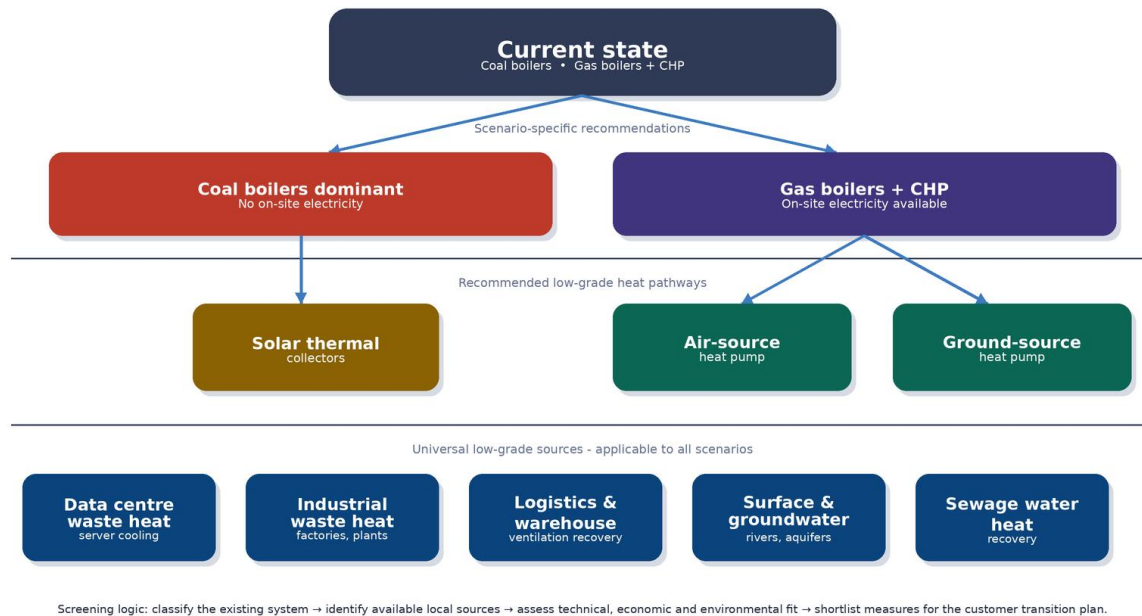


Figure 6: Indicative decision-making process for technology selection

The main technology options considered for integrating low-grade renewable energy and recovered heat into district heating systems are presented below.

**Heat pumps:** Upgrade low-temperature heat from air, water, the ground or recovered-heat streams to the temperature required by the district heating network. They should be considered where a suitable low-grade heat source and sufficient electricity supply are available. The main configurations considered in this roadmap are:

- **Air-source heat pumps:** These systems extract heat from ambient air and are generally easier to deploy than configurations requiring access to water sources or drilling. They are most suitable where rapid deployment, relatively low investment and limited infrastructure requirements are priorities. Their main limitation is that efficiency and heat output decrease during cold weather, when heat demand is typically highest.
- **Water-source heat pumps:** These systems recover heat from groundwater, rivers, lakes, seawater, wastewater, mine water or other water streams. They should be considered where a stable source with adequate flow and temperature is available close to the network. Water-source systems can provide more consistent performance than ambient-air systems, although they may require wells, intake structures, filtration systems, heat exchangers and connection pipelines.
- **Ground-source heat pumps:** These systems use shallow geothermal energy extracted through boreholes or ground loops. They should be considered where stable and predictable performance is required and sufficient land is available. Their main limitation is the relatively high investment associated with drilling and ground heat exchangers.

**Solar Thermal Collectors:** Produce heat directly from solar radiation. They should be considered where sufficient unshaded land or roof area is available. Their suitability depends on local solar irradiation, available space, seasonal correspondence between production and demand, and compatibility with network temperatures. The main collector types considered are:

- **Flat-plate solar thermal collectors:** These collectors are most suitable for low- and medium-temperature applications, particularly for supplying summer demand, preheating return water or charging thermal storage systems. They are generally simpler and less expensive than evacuated-tube collectors but require sufficient collector area and perform less effectively at high operating temperatures.
- **Evacuated-tube solar thermal collectors:** These collectors should be considered where higher output temperatures or improved performance under colder conditions are required. They may be more suitable for networks operating at elevated temperatures, although their improved performance must be balanced against their higher investment cost.

**Waste heat recovery:** Uses surplus heat from industrial facilities, wastewater treatment plants, data centres and other processes. Depending on the temperature available, recovered heat may be supplied directly through a heat exchanger or upgraded using a heat pump. The source should be sufficiently large, reliable and located within a feasible distance of the district heating network. The assessment should consider its temperature and availability profile, distance from the network, connection requirements, dependency on third parties and long-term availability.

**Thermal energy storage:** Retains heat for later use and helps balance differences between heat production and demand. It should be considered as an enabling technology where heat generation and consumption do not occur simultaneously. It is particularly relevant for integrating variable sources such as solar thermal energy, increasing heat-pump operating hours and reducing peak-load requirements. Its suitability depends on the required storage capacity and duration, available space, operating temperatures, expected heat losses and additional investment requirements.

The conceptual integration scheme is a standard element of the technical assessment and provides a high-level representation of the proposed system configuration. It shows the main generation units, energy flows and interactions between the available heat sources, supporting infrastructure and the district heating network. The figure below presents this standard output for the Rogoźno case.

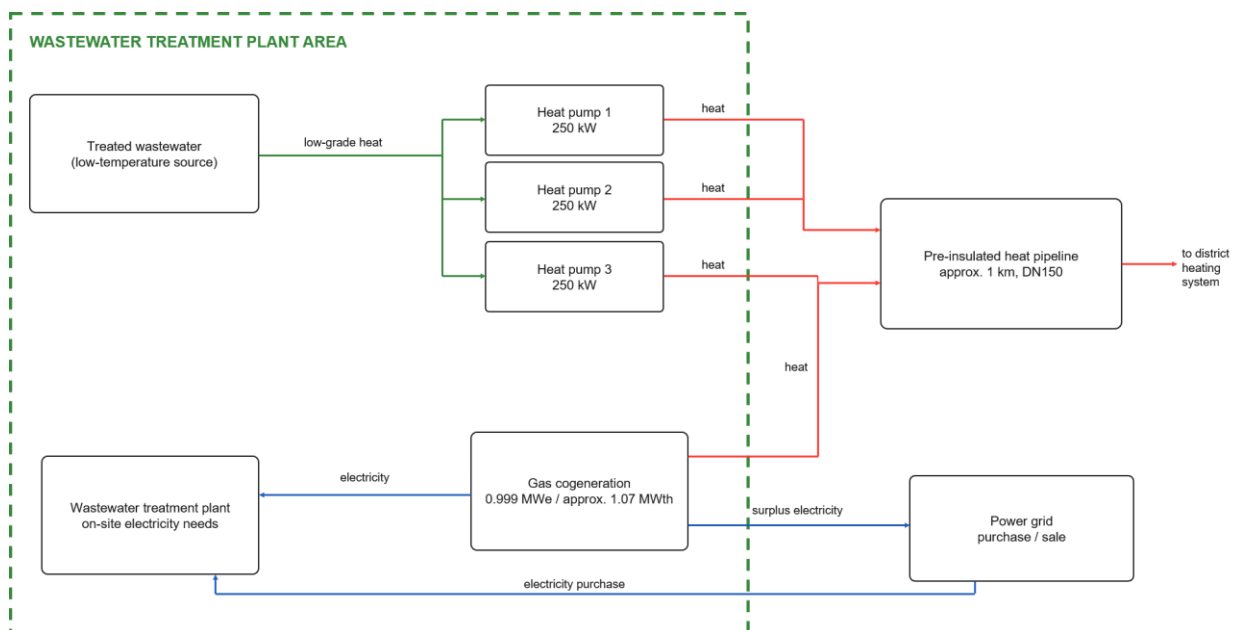


Figure 7: Conceptual integration scheme for the Rogoźno project

The monthly heat production chart is another standard element of the technical assessment and shows the expected contribution of each heat generation technology throughout the year. It supports the assessment of the operational role of each technology, the distribution of heat production between base-load and peak-load assets, and the contribution of the proposed configuration to system decarbonisation. The figure below presents this standard output for the Rogoźno case.

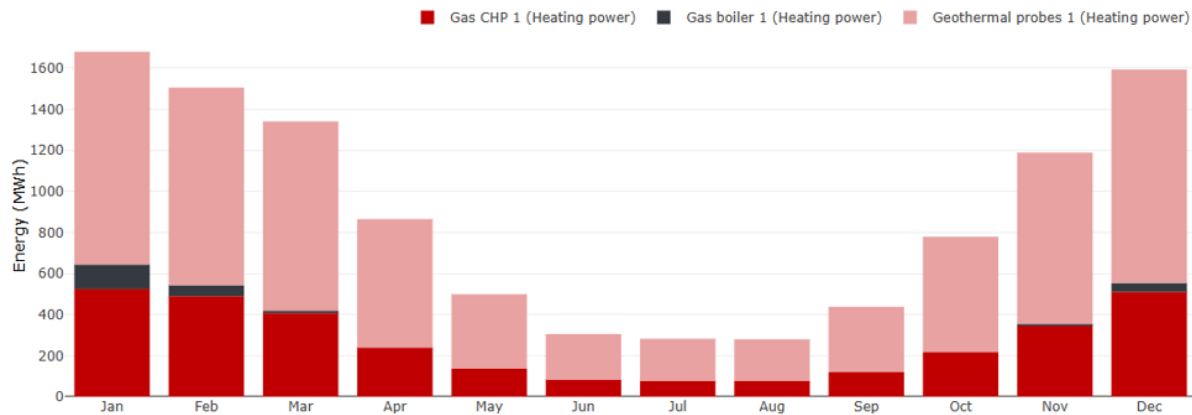


Figure 8: Monthly heat production by generation technology.

The output of this stage is the definition of the technology components required for each technically feasible scenario, their expected role within the system, the key design assumptions and the rationale for their inclusion. This provides the basis for the subsequent financial comparison of the technically feasible scenarios.

## FINANCIAL PLAN DEVELOPMENT

The Financial Plan Development stage assesses the financial viability of the technically feasible scenarios identified in the previous stage and supports the identification of the preferred replication scenario and its indicative financing structure. The analysis should compare each technical scenario against the baseline configuration and evaluate the incremental financial implications of the proposed investment.

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The financial assessment should be based on the Free Cash Flow to Firm (FCFF) approach, using a discounted cash flow (DCF) methodology. Calculations should be performed on an incremental basis, considering only the revenues, costs and investments that change as a result of implementing each scenario. This approach allows the direct comparison of alternative decarbonisation pathways against the baseline scenario and supports the identification of the scenarios with the strongest financial performance.

To ensure comparability between scenarios, a common set of assumptions should be defined and consistently applied throughout the analysis. These assumptions should include:

- Investment period and analysis horizon
- Reference year for discounting cash flows
- Discount rate<sup>1</sup>
- Nominal or real price basis
- Fuel, electricity and CO<sub>2</sub> price forecasts
- Heat demand and production assumptions
- Operating hours and system performance assumptions
- Asset replacement and reinvestment assumptions
- Residual value assumptions at the end of the assessment period

The financial model should be developed in a flexible spreadsheet environment that allows key assumptions to be modified and tested. This facilitates sensitivity analysis to assess the impact of changes in the most influential variables, such as energy prices, investment costs, operating costs, discount rates and CO<sub>2</sub> prices. Sensitivity analysis is essential for understanding project risks and identifying the conditions under which each scenario remains financially viable.

All assumptions, calculation parameters and data sources should be clearly documented and applied consistently across all scenarios to ensure transparency, reproducibility and comparability of results. The results should support the comparison of the technically feasible scenarios, the identification of the preferred replication scenario and the subsequent definition of its financing strategy and implementation plan.

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<sup>1</sup> As a reference value, projects can use a discount rate reflecting the weighted average cost of capital (WACC) applicable to the selected financing structure. In the Rogoźno investment plan, a post-tax discount rate of 3.36% was applied based on the financing assumptions used for the project. This value is specific to the Rogoźno case and should not be interpreted as a general benchmark. The appropriate discount rate for each replication project should reflect its specific financing conditions, country context, technology risks, project structure and investor requirements.

## REVENUES

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The revenue assessment should identify the income streams affected by the implementation of each technically feasible scenario. As the financial analysis is conducted on an incremental basis, only revenues that change relative to the baseline scenario should be included.

District heating revenues are typically associated with heat sales and contracted thermal capacity. Depending on the applicable regulatory framework, the tariff may include an energy charge linked to heat consumption and a capacity charge linked to contracted thermal capacity. The applicable tariff methodology, approval process and regulatory conditions should therefore be reviewed before projecting future revenues.

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Where heat tariffs are regulated or subject to public approval, the assessment should examine whether the investment and operating costs of the preferred scenario can be recovered under the applicable tariff methodology. It should also assess the expected impact on the final heat price and identify any affordability or regulatory constraints that could prevent implementation, even where the scenario is technically feasible and shows positive financial performance.

Depending on the selected technology and local conditions, the following revenue categories may be considered:

- Heat sales to existing customers
- Additional heat sales resulting from network expansion or increased demand
- Revenues associated with contracted thermal capacity
- Electricity sales, where CHP units or other electricity-generating technologies are included in the system

When the investment does not affect heat tariffs or the demand served, the same heat revenues may be assumed across the alternative scenarios. In such cases, differences in financial performance will primarily result from incremental investment, operating costs, energy consumption and avoided fuel, heat-purchase and emission-related costs rather than from changes in revenue.

The output of this step is an incremental revenue projection for each scenario over the analysis period. The projections should be consistent with the heat demand and production requirements forecast, operating assumptions and applicable tariff methodology, with all assumptions clearly documented to ensure transparency and comparability across scenarios.

## COSTS

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The cost assessment should quantify all expenditures associated with the implementation and operation of each technically feasible scenario. As with revenues, the analysis should be performed on an incremental basis, considering only the costs and investments that change relative to the baseline scenario.

Costs should be divided into capital expenditure (CAPEX) and operating expenditure (OPEX) to provide a comprehensive assessment of the financial implications of each alternative.

CAPEX should include all investment costs required to design, construct and commission each technically feasible scenario. Depending on the technologies considered, these may include:

- Main heat generation and recovery equipment
- Heat pumps, heat exchangers and thermal storage systems
- Equipment replacement needs over the project lifetime

- Boreholes, wells, intake structures and source-specific infrastructure
- Solar thermal collector fields and associated equipment
- Pipelines and district heating network connection works
- Electrical infrastructure and grid connection upgrades
- Civil works and site preparation
- Engineering, permitting and project development costs
- Installation and commissioning activities
- Contingency allowances, where appropriate

Replacement investments should be scheduled according to the expected useful life of each asset and included in the cash-flow projections for the year in which they are expected to occur. Any residual value remaining at the end of the analysis period should be treated consistently with the assumptions established for the financial model.

The level of detail should be sufficient to compare the alternative scenarios, identify the main investment cost drivers and determine the timing of the required expenditure.

A CAPEX schedule is a standard output of the cost assessment and provides a structured breakdown of the investment by cost category and expected year of expenditure. The schedule supports the verification of total investment requirements, the preparation of annual cash-flow projections and the subsequent definition of the financing needs. The table below presents this standard output for the Rogoźno case.

**Table 1: Indicative CAPEX schedule for the Rogoźno project**

| No. | Item                                                              | Expenditure [PLN] | 2025           | 2026             | 2027             | 2028             |
|-----|-------------------------------------------------------------------|-------------------|----------------|------------------|------------------|------------------|
| 1.  | Preparatory works                                                 | 650 000           | 130 000        | 520 000          |                  |                  |
| 2.  | Gas cogeneration 0,999 MWe                                        | 6 700 000         |                | 2 010 000        | 4 020 000        | 670 000          |
| 3.  | Water heat pump system at the wastewater treatment plant 0,75 MWt | 5 100 000         |                | 1 530 000        | 3 060 000        | 510 000          |
| 4.  | District heating network 1 km (2 × DN150)                         | 2 300 000         |                | 690 000          | 1 380 000        | 230 000          |
|     | <b>TOTAL CAPITAL EXPENDITURE</b>                                  | <b>14 750 000</b> | <b>130 000</b> | <b>4 750 000</b> | <b>8 460 000</b> | <b>1 410 000</b> |

OPEX should reflect the recurring costs incurred during the operation of each scenario. The assessment should consider:

- Electricity consumption
- Fuel purchases, where applicable
- Heat purchases from external suppliers
- Operation and maintenance costs
- Labour and service contracts
- Emission allowance costs
- Insurance and administrative costs
- Other technology-specific operating expenses

In addition to direct expenditures, the assessment should quantify the costs avoided as a result of implementing each scenario. These savings should be estimated relative to the baseline configuration and may include:

- Reduced fossil fuel consumption.
- Reduced heat purchases
- Reduced CO<sub>2</sub> emission costs

Avoided costs should be incorporated into the annual cash-flow projections in the periods in which the corresponding savings are expected to occur.

The output of this step is an incremental CAPEX and OPEX projection for each scenario over the analysis period, together with the associated avoided costs. All cost assumptions should be clearly documented and applied consistently across the scenarios to ensure transparent and comparable results.

## FINANCIAL ANALYSIS

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The financial analysis assesses the economic performance of the technically feasible scenarios identified in the previous stage. The evaluation should be conducted on an incremental basis, comparing each alternative scenario against the baseline configuration and considering only the revenues, costs and investments that change as a consequence of implementing the scenario.

The analysis should apply a discounted cash flow (DCF) approach using the Free Cash Flow to Firm (FCFF) methodology. Annual cash flows should be calculated over the selected analysis period by combining the incremental revenues, operating costs, avoided costs and capital expenditure associated with each scenario.

The main financial indicators used to assess project performance should include:

- **Net Present Value (NPV):** Measures the present value of future cash flows generated by the project, discounted over the analysis period. A positive NPV indicates that the investment generates value and exceeds the selected discount rate.
- **Unleveraged Internal Rate of Return (IRR):** Represents the discount rate at which the project's NPV equals zero, indicating the return generated by the project before financing costs are considered.
- **Net Present Value Ratio (NPVR):** Measures the value created per unit of investment, allowing comparisons between alternatives with different investment scales.
- **Simple Payback Time (SPBT):** Indicates the number of years required to recover the initial investment without considering the time value of money.
- **Discounted Payback Time (DPBT):** Indicates the number of years required to recover the investment while accounting for discounting.
- **EBITDA:** Measures the operating profitability of the project before interest, taxes, depreciation and amortisation.

These indicators should be calculated consistently for all technically feasible scenarios. The results should be presented in a comparative format to facilitate decision-making and highlight the trade-offs between investment requirements, operating savings and expected financial returns.

A financial indicator comparison table is a standard output of the financial analysis and provides a structured summary of the investment requirements and financial performance of the scenarios assessed. This format supports the direct comparison of scenarios with different investment levels,

cost structures and expected returns. The table below presents this standard output for the Rogoźno case.

**Table 2: Comparison of financial indicators for the Rogoźno project scenarios**

| No. | Item                                          | Unit  | Low2High variant | Comparative variant |
|-----|-----------------------------------------------|-------|------------------|---------------------|
| 1.  | Expenditure                                   | PLN   | 14 750 000       | 8 600 000           |
| 2.  | NPV                                           | PLN   | 6 548 725        | 10 715 610          |
| 3.  | IRR                                           | %     | 10,89%           | 17,76%              |
| 4.  | NPVR                                          | %     | 49,15%           | 137,82%             |
| 5.  | Simple payback period SPBT                    | years | 10,30            | 7,73                |
| 6.  | Discounted payback period DPBT                | years | 12,97            | 9,17                |
| 7.  | Operating profit from the investment (EBITDA) | PLN   | 19 873 090       | 18 490 896          |

A sensitivity analysis should also be performed to assess how changes in the main assumptions affect the financial performance of each scenario. The financial model should allow the relevant input values to be modified and their impact on indicators such as NPV, Project Unlevered IRR and payback time to be assessed.

The analysis should consider, at least:

- Capital expenditure
- Electricity purchase prices
- Fuel prices
- CO<sub>2</sub> emission allowance prices under the applicable emissions trading system
- Electricity selling prices where cogeneration is included

The variables tested should be adapted to the characteristics of each scenario and assessed on an incremental basis. Heat-pump-based scenarios may be particularly sensitive to changes in capital expenditure and electricity purchase prices, while scenarios incorporating cogeneration may also be affected by electricity selling prices. Changes in fossil fuel and emission allowance prices may influence the value of the costs avoided relative to the baseline scenario.

A sensitivity chart is a standard output of this analysis and shows how changes in the selected assumptions affect the financial performance of the scenario assessed. It supports the identification of the variables with the greatest influence on project profitability, the comparison of scenario resilience and the assessment of the conditions under which the investment remains financially viable. The figure below presents this standard output for the Rogoźno case.

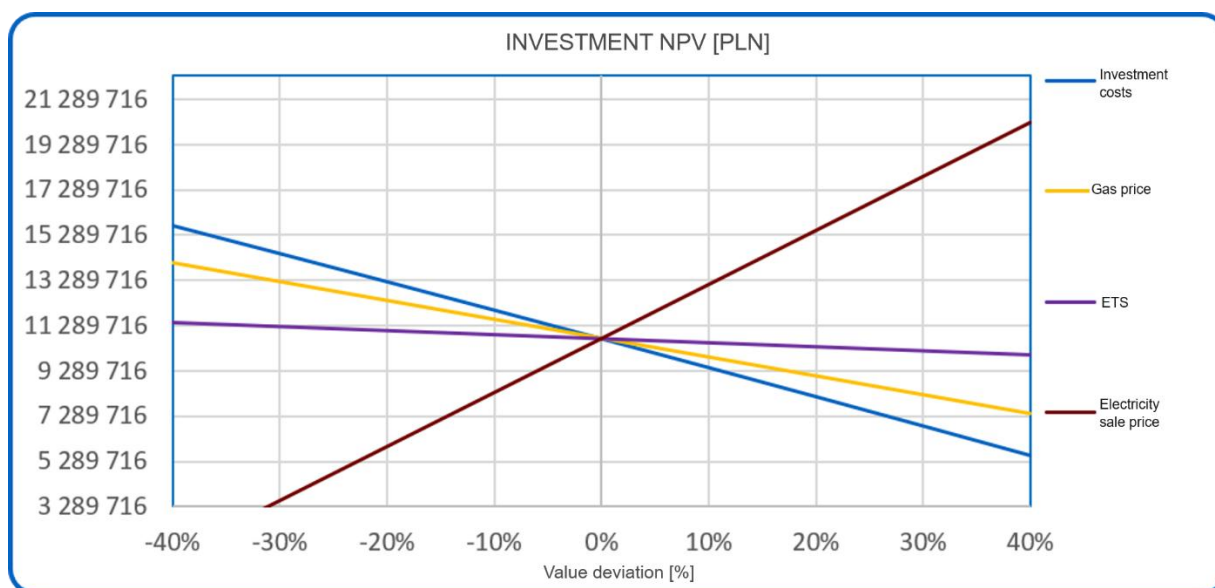


Figure 9: Sensitivity analysis of the financial performance of the Rogoźno project

The output of this step is a comparative assessment of the financial performance and resilience of the technically feasible scenarios, including incremental cash-flow projections, profitability and payback indicators, and sensitivity analysis of the main financial variables. The results should identify the assumptions with the greatest influence on project profitability and the conditions under which each scenario remains financially viable, providing the basis for selecting the preferred replication scenario and defining its financing structure.

#### FINANCIAL STRUCTURE

The financing structure defines how the preferred scenario will be funded once its financial viability and overall financing requirements have been established. The objective is to identify an affordable combination of funding sources that is consistent with the project's expected cash flows, risk profile and ownership structure.

District heating decarbonisation projects are generally implemented by established operators or public entities that retain ownership and operational control of the assets. They may also involve relatively high upfront investment, moderate financial returns and long payback periods, which can limit their attractiveness to external equity investors. At the same time, regulated or contractually supported heat revenues may provide relatively stable and predictable cash flows, although their adequacy should be assessed for each project.

Under this structure, liability may extend beyond project revenues and lenders may rely on the broader financial capacity, balance sheet and assets of the project owner or implementing entity. This structure may be appropriate where the project is implemented and financed directly by an established district heating operator or public authority, although the preferred approach should be adapted to the ownership structure, project scale, risk allocation and financial capacity of the promoter.

The financing plan should combine different funding sources to achieve an affordable investment structure. Depending on the project characteristics, the financing package may include:

- Own resources of the project owner or implementing entity

- Non-repayable funding, including grants and public support schemes
- Repayable financing, including public, promotional and commercial loans

An indicative financing structure is a standard output of this step and shows how own resources, grants and repayable financing can be combined to cover the project's investment requirements. The figure below presents an indicative with-recourse financing structure.

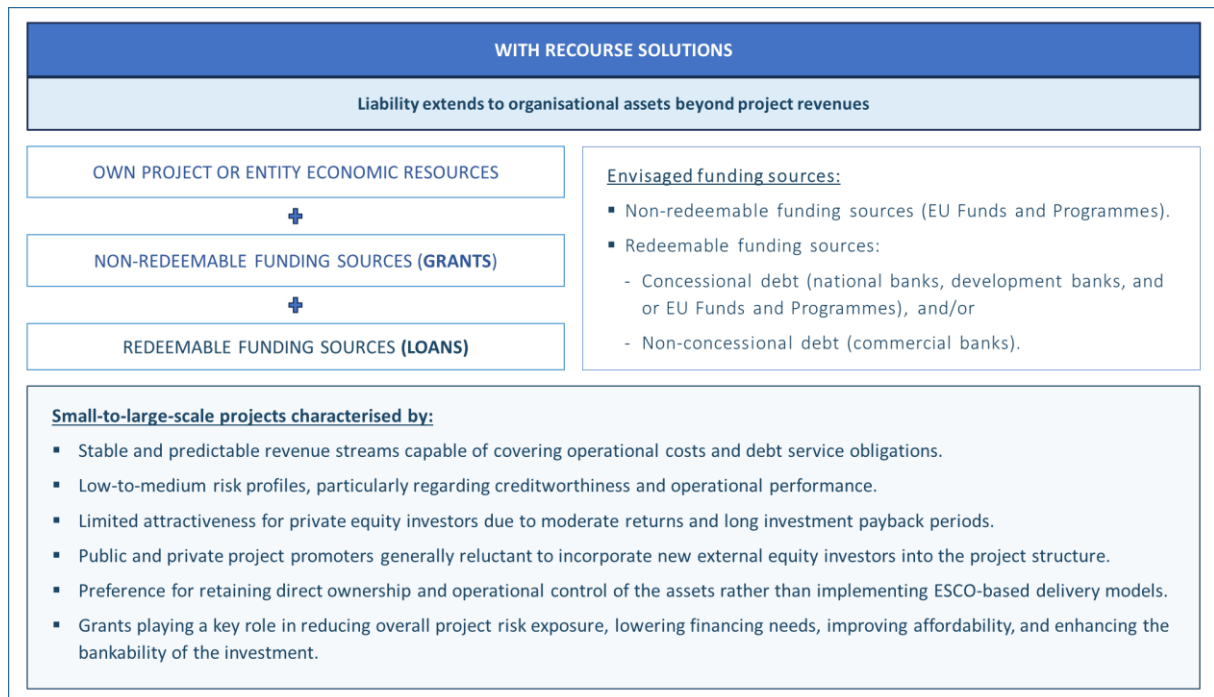


Figure 10: Indicative with-recourse financing structure for district heating projects

Redeemable financing may take different forms depending on the project characteristics and financing conditions available in the market. These may include:

- Concessional debt from national promotional banks, development banks or public financing programmes
- Financing instruments supported by EU funds and programmes
- Conventional debt provided by commercial banks and financial institutions

The appropriate combination of funding should be defined by assessing:

- Total investment requirement
- Eligible and non-eligible project costs
- Available own resources
- Potential grant amount and aid intensity
- Remaining financing requirement after grants and own resources
- Loan amount, interest rate, maturity and repayment profile
- Capacity of project cash flows to cover operating costs and debt service
- Creditworthiness and guarantees required from the borrower
- Eligibility and compatibility of the selected financial instruments

Financing options should be tested against the promoter's ownership structure, legal and regulatory status, borrowing capacity, procurement requirements, available guarantees and capacity to service debt. The identification of a potentially relevant instrument does not imply eligibility, financing approval or availability of funds, which must be confirmed with the corresponding managing authority or financing institution.

Grants can improve project bankability by reducing upfront financing needs and mitigating specific project risks. However, public funding alone is unlikely to cover the scale of investment required for the energy transition. Financing strategies should therefore seek to mobilise private capital and use grants strategically to improve affordability and leverage additional investment rather than treating them as the primary funding source. The European Commission's 2026 recommendation on unlocking private investment in energy efficiency similarly highlights the need to expand repayable instruments, mobilise private finance and reduce reliance on predominantly non-repayable public support.

The assessment should identify all relevant funding programmes and evaluate their eligibility requirements, supported technologies, beneficiary categories, aid intensity limits, minimum investment thresholds, and compatibility with other funding sources.

The output of this step is an indicative financing structure for the preferred scenario, showing the expected contribution of grants, debt and own resources, the proposed debt conditions and any remaining funding gap. The structure should also demonstrate the project's capacity to meet its debt-service obligations under the assumptions assessed. Where the financing requirement is not fully covered, alternative measures should be considered, such as additional support, a higher own contribution, revised debt conditions or adjustments to the investment scope.

In line with D6.6, the assessment should conclude with a concise implementation action sheet identifying the preferred scenario, the main unresolved assumptions, responsible parties, permitting and financing milestones, the next decision gate and the immediate actions required.

## CONCLUSIONS

This Local Replication Roadmap shows how existing high-temperature district heating systems can integrate low-grade renewable energy sources and waste heat. Their effective use depends on appropriate technical integration, long-term planning and a supportive regulatory framework. These three dimensions must be assessed together.

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The suitability of a low-grade heat source depends on its specific context, including its temperature and availability, distance to the network, required supply and return temperatures, demand profile and network characteristics. Its integration potential must therefore be assessed using representative operating data rather than isolated measurements or predetermined technology choices.

In high-temperature networks, hybrid and modular configurations are often more suitable than the full replacement of existing generation capacity. Low-grade heat sources and heat pumps can cover baseload demand, while higher-temperature technologies and existing boilers can meet peak demand, maintain the required temperatures and ensure security of supply. This approach enables gradual decarbonisation without compromising system reliability.

The Rogoźno case shows that technologies should not be assessed in isolation. The performance of each solution depends on the interaction between the heat source, heat pumps, cogeneration units, existing boilers and network conditions. It also shows that short-term profitability and long-term strategic value may differ. A solution with a shorter payback period may offer lower decarbonisation benefits or reduced long-term strategic value. Technology selection should therefore consider financial, technical, environmental and regulatory criteria.

Finally, technical feasibility and financial viability must be supported by an implementable financing structure. Grants can reduce financing needs and project risks, but they should complement rather than replace own resources, debt and private capital. Mobilising private investment requires reliable operating data, credible financial projections, appropriate risk allocation and a clear long-term regulatory pathway.

Overall, successful replication does not depend on replicating a standard technological solution or applying the Rogoźno configuration unchanged. It requires a consistent decision-making process adapted to local conditions. The roadmap provides this process, supporting district heating operators and local authorities in developing technically sound, financially credible and implementation-ready decarbonisation projects.