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Lead Beneficiary	CREARA
Lead Authors	David Pérez, Creara Gabriel García, Creara Paula Cavarischia, Creara
Contributors	Galina Ivanova (EP), Rolandas Urbonas (LEI), Álvaro Salamanca (GNE)
Submitted by	Gabriel García Hernández
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More information on the project can be found at: https://www.low2highdh.eu/

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Executive Summary

Low2HighDH aims to support district heating (DH) operators in Lithuania, Poland, and Slovakia by integrating low-grade and waste heat technologies into their systems. This approach helps operators meet decarbonisation goals while promoting sustainable energy practices. To achieve this, the project requires active engagement from high-temperature DH sites and a thorough prefeasibility evaluation of different case studies.

The objective of this document is to provide comprehensive guidance for the completing the necessary template to structure information effectively during the case study development process. This will involve completing several files to enable data collection and management. This process ensures a thorough case study definition.

The document has been divided into three main sections:

- Guidelines on how the market analysis should be conducted to understand the environment in which the project will be implemented. The legal and regulatory analysis complement the market one to ensure that the Low2HighDH project complies with all applicable regulations and maximises the available incentives.
- An overview of the Low2HighDH project's technical analysis and the expected results within the project framework.
- A description of the financial analysis to assess the economic viability of the project, from estimating the initial investment to the projection of revenues and the identification of possible sources of financing.

This deliverable functions as both a template and a structured guide for developing each selected site's case study. Each section of the deliverable corresponds to a section of the template. It describes in detail the steps, methodologies, and criteria to be adapted and developed according to the unique characteristics of each location. This structure provides a general framework that ensures uniformity while allowing flexibility to address site-specific requirements.

By incorporating local regulatory, social, and technical conditions, the deliverable ensures that each case study is comprehensive and consistent. It serves as an adaptable tool for efficient and organised project implementation, offering both guidance and a framework for consistency across different sites and countries.

List of Acronyms and Abbreviations

Abbreviation	Definition
GA	Grant Agreement
CA	Consortium Agreement
EC	European Commission
EU	European Union
EED	Energy Efficiency Directive
WP	Work Package
DH	District Heating
GHG	GreenHouse Gas
LCOH	Levelised Cost Of Heat
CAPEX	CAPital EXpenditure
OPEX	OPerating EXpenditure
IRR	Internal Rate of Return
P&L	Profit and Loss
EPC	Engineering, Procurement, and Construction
ESC	Energy Service Company
PPA	Power Purchase Agreement
BOO	Build, Own, Operate
BOT	Build, Operate, Transfer

Market analysis. Demand analysis of heat from DH

Market analysis is a key component of the Low2HighDH project, helping to align its objectives with EU's critical challenges. On the other hand, it facilitates the assessment of feasibility and impact, considering current conditions and expected developments in the different target countries. This analysis identifies projected market trends, studying competition, assessing the prices and cost of energy and taking into consideration the regulatory factors.

TRENDS AND LOCAL CONTEXT

First, there is a need to estimate the historical trends in DH usage in each target country. This includes the identification of the evolution of total heat demand by studying the historical evolution of heat consumption in the target markets and analysing how political, economic and technological trends have influenced demand. Besides this, it is necessary to review and research on:

- Evolution of number of consumers: evaluate the growth or decline in the number of DH network users. Highlighting how network expansion programs, population density and local strategies have impacted this growth.
- Evolution of average consumption per consumer: analysis of how average consumption per consumer has changed over time, exploring factors such as energy efficiency improvements, building modernization and changes in consumption habits.

RETAIL PRICES ANALYSIS

The price analysis requires a comprehensive review of the current and existing regulations as well as the evolution of energy tariffs over the last years and decades. Moreover, assessing the evolution of electricity and fuel costs over the years provides insights into patterns and potential future fluctuations.

- Analysis of price historic evolution: description of how DH retail prices have evolved in recent years or decades. It is necessary to identify trends related to input cost fluctuations, regulations, or technological changes.
- Analysis of price components and historic evolution: by breaking down the components of retail prices (energy, transport, maintenance, taxes) and analysis of how each has evolved historically.
- Explanation and comments about historic price evolution: provide a critical analysis of the reasons behind price developments, identifying economic, political, and technical factors.

IDENTIFICATION AND ANALYSIS OF ANY OTHER MARKET TRENDS

- Analysis of competing sources of heat: identify the main sources of competition (individual systems, green energy, thermal waste energy). Compare their advantages/disadvantages versus DH and explore future projections for these alternatives.

- Reduction/change of requested temperatures: analyse and identify trends towards low-temperature networks and how these impact technology, costs, and heat demand.
- Any other relevant trends: include any other significant trends that may influence DH demand, such as urbanization, climate change or emerging energy policies.

Analysis of regulatory considerations

This part is about dedicated to assessing the regulations affecting the sector, including limitations on prices, minimum or maximum temperatures, and or sustainability criteria. The aim is to highlight regulatory challenges in each target market and how they impact project design.

The main objective of the legal analysis is to provide decision-making support, ensuring that the project is resilient to potential challenges. This includes ensuring that the project complies with all applicable European, national, and regional regulations, such as those in the Directive (EU) 2023/1791 on Energy Efficiency Directive (EED). This EED specifies sustainability criteria for DH and cooling systems, including maximum allowable Greenhouse Gases (GHG) per unit of heat supplied to consumers (g/kWh), and requires an increase in primary energy efficiency and renewable energy share in these systems.

In terms of regulatory and policy considerations, a comprehensive review of European regulations is essential, particularly of those relevant to DH systems, such as the Directive on the promotion of renewable energy, the Directive on emissions reduction, and the Directive on the energy performance of buildings. These legal frameworks are important for ensuring that the DH sites are aligned with EU goals for decarbonization and sustainability.

Besides this, a regulatory study will be conducted to focus on the key aspects that may significantly impact DH sites in each country. This analysis will cover the legal framework affecting DH operations, as well as specific sales-related constraints, such as price controls or minimum temperature requirements, among others. DH operators possess deep expertise in these matters, as they deal with them daily; therefore, their support will be crucial to gain understanding of the national context for each DH site.

Additionally, national and regional licensing and compliance requirements will be reviewed, along with government incentives, subsidies, or tax exemptions relevant to DH projects. Collaboration with local partners will be essential to identify specific regulations, permits, and available incentives in each target country, ensuring the provision of detailed and actionable insights.

Forecasting demand

The last step is an assessment of growth expectations based on political trends in each country and the technologies in place. E.g. focus is on next-generation technologies and increasing per capita consumption, network expansion needs, etc.

- Identification of proxies (if needed): selection of key indicators or variables (e.g. population, urbanization, energy consumption) that can be used as proxies for projecting future demand.

- Analysis: Analytical models will be developed, placing particular emphasis on expert criteria and long-term trends shaping the sector. These models will aim to provide robust and forward-looking insights, leveraging the expertise of stakeholders to ensure relevance and alignment with evolving industry dynamics.
- Expected volumes: projection of expected volumes of heat demand, identifying optimistic, conservative, and pessimistic scenarios.

Technical analysis

The next step of the template is to conduct a technical analysis to evaluate the feasibility and specific requirements for implementing the Low2HighDH project in the different sites chosen.

The technical analysis of the project should be comprehensive addressing the complete transformation of the DH system. First, an evaluation of the existing DH infrastructure must be carried out, including an analysis of the capacity and efficiency of the generation plants, as well as an evaluation of the piping and potential areas of heat loss. This will be followed by a thorough investigation to identify applicable clean technologies that can leverage available waste heat sources in the area, along with plans for potential renovations and expansions to improve the efficiency of the existing heat network.

Evaluation of existing infrastructure

The evaluation of the existing infrastructure at the DH site can be conducted by assessing the design and current capacity of the DH network through communication with local partners, followed by an analysis of the efficiency and the different emissions of the existing generation plants.

As a result, the current state of the system components is evaluated, including identifying areas of heat loss, and assessing the conditions and age of the various pipelines and generation stations. Finally, the site's current thermal demand and the system’s flexibility for integrating new technologies are determined.

- Evaluation of current DH assets: description of the current state of the district heating infrastructure, including generation plants, distribution networks and storage systems. Identify areas of thermal losses and technological limitations.
- Capacity and efficiency analysis: assess the current capacity and operational efficiency of generation plants.
- Pipeline assessment: analyse the condition of pipes, including age, materials, and susceptibility to heat loss.
- System flexibility for integration: determine the adaptability of existing infrastructure to integrate new technologies, especially low temperature renewable energy solutions (LGERES).

Technologies to be used

Identification and quantification of available heat sources

- Amount of heat: quantifying available heat sources, such as industrial waste energy, sewage waste heat, other sources of WH (datacenters, malls, etc.) geothermal energy, solar energy, or biomass. The aim is to identify how much heat can be harnessed to feed the DH network.
- Heat profile: it is necessary to analyse in detail the thermal characteristics of each heat source, such as available temperatures and availability patterns (constant, seasonal, etc.).
- Additional investments: estimation of the investments needed to exploit each heat source, such as new equipment, transport systems or modifications to the existing network.

Analysis of the solutions studied

Following the development of an extensive analysis of the 10 specific case studies, diverse ways in which specific technologies can facilitate the integration of LGERES into DH systems were explored. Although 24 technologies were described in the Deliverable 2.2 portfolio of technical solutions, only those that showed the highest feasibility to in reduce fossil fuel dependency and GHG emissions in applied scenarios were used.

After analysing the technical solutions, some of them were selected for developing the 10 case studies on how these solutions could be applied in real scenarios to facilitate the integration of LGERES in DH networks. A summary of the possibilities analysed for implementation is outlined.

Table 1 Summary of possible technical solutions from D2.2

Case study Nº	Tech. Sol. Nº	Solution	Description	Benefits	Limitations
01	05	High-Temperature Solar Integration in CHP Systems	Integration of solar thermal energy into a Combined Heat and Power (CHP) system using solar concentrators to inject high-temperature heat into the DH system	Significant reduction in carbon emissions	Increase in CAPEX
02	11	Flat Plate Solar Panels and Steam Heat Pump Integration	Flat plate solar panels with a steam vapor compression heat pump to upgrade low-temperature heat to levels suitable for DH networks	High efficiency in regions with high solar irradiance	Depends on waste heat recovery
03	13	Parabolic Trough Solar Integration	Use of parabolic trough solar collectors to preheat water for DH systems, reducing fossil fuel consumption without major infrastructure changes	Reduction in fossil fuel consumption	Limited to preheating water
04	18	Industrial Waste Heat Recovery	Recovery of industrial waste heat using an absorption heat	Low-cost solution (LCOH) with	Reliant on sources of

		with Absorption Heat Pump	pump to supply heat to a DH network	quick payback period	industrial waste heat
05	19	Waste Heat and Low-Temperature Heat Pump Combination	Integration of low-temperature industrial waste heat with steam compression heat pumps for DH systems, ideal for retrofits	Significant reductions in energy costs and emissions	Requires sources of low-temperature waste heat
06	22	Geothermal Heat Pump Integration	Replacement of traditional fossil fuel boilers with geothermal heat pumps for DH networks	Environmental benefits and long-term sustainability	Higher LCOH compared to other options
07	24	Sewage Waste Heat and Steam Compression Heat Pump	Recovery of heat from municipal sewage using a vapor compression heat pump, ideal for urban areas	Cost savings in urban areas	Limited to areas with access to sewage heat sources
08	05.1	CHP Retrofit with Solar Concentrators	Detailed integration of high-temperature solar concentrators into existing CHP systems, providing high environmental benefits but requiring high CAPEX	Strong environmental benefit	Requires subsidies or incentives
09	23	Boiler Substitution with Biomass	Replacement of traditional boilers with biomass alternatives, significantly reducing carbon emissions	Significant reduction in carbon emissions	Depends on local availability of biomass
10	24	Boiler Substitution with Waste Heat and MVR Systems	Replacement of boilers with waste heat recovery and Mechanical Vapor Recompression (MVR), particularly efficient in industrial areas	High efficiency and cost savings	Dependent on availability of waste heat

Modelling and simulation with nPro

To carry out this process in a comprehensive and precise manner, the nPro software tool will be used, which allows for the modelling and simulation of complex energy systems. In this case, nPro will be used to create an initial model of the existing DH system, including the distribution networks and current generation plants. The goal is to conduct simulations and evaluate different scenarios for the renewal and expansion of the network, using low-temperature renewable energy solutions to achieve design optimisation to maximise the efficiency and cost-effectiveness of the system. The steps will follow the next structure:

- Baseline modelling: describe how nPro will be used to model the current DH system, including generating plants and distribution networks.

- Scenario simulation: simulate different scenarios of integration of renewable technologies, such as waste heat recovery or solar energy, and analyse their impact on efficiency, costs and emissions.
- Optimisation: optimise system design through simulations to maximise energy efficiency and economic profitability.

Finally, an analysis of the energy balances and CO_2 emission reductions will be conducted for each proposed scenario. nPro will enable an accurate technical assessment, facilitating informed decision-making on the best strategies for transforming of the DH system towards a more sustainable and efficient model.

Economic and CO_2 emissions impact assessment

As explained in the analysis of the technical solutions portfolio developed by the partners in the consortium, the Low2HighDH project requires a phased transition, beginning with hybrid systems that combine fossil fuels and renewable energy sources, before progressing to fully renewable heating systems. This phased approach allows the integration of LGERES into existing grids without disrupting the heat supply, while making use of existing infrastructure.

- Comparison of CAPEX and OPEX with conventional systems (Business-as-Usual (BAU) analysis): Compare the traditional fossil fuel-based heating model with the proposed solutions in terms of capital expenditure (CAPEX) and operating expenditure (OPEX). Additionally, evaluate the economic feasibility of the proposed solutions using metrics such as the levelized cost of heat (LCOH) to provide a comprehensive cost assessment.
- Cost analysis by technology: break down implementation costs for selected technologies, from waste heat recovery to solar energy integration. Consider applicable subsidies or incentives.
- Emissions of CO_2 analysis: evaluate the current emissions of the DH system to establish a benchmark, calculate the projected reductions for each technology scenario, and quantify the long-term impact in terms of decreased fossil fuel dependency and alignment with European sustainability goals.

An important aspect is the financial and operational feasibility of the proposed solutions. The LCOH is used as the main measure to assess the cost-effectiveness of different technological strategies. While some solutions, such as waste heat recovery, offer lower LCOH and immediate economic benefits, others, such as retrofitting existing systems with geothermal or solar technologies, may require higher initial investments, but provide long-term environmental and economic benefits. According to the report previously developed by the consortium on the technical solutions portfolio, it is concluded that, despite possible short-term cost increases, the LCOH of renewable solutions remains competitive in the European energy market, especially when considering the long-term reduction of carbon emissions and reliance fossil fuels. Additionally, the impact of cost reduction externalities is a significant factor.

Financial analysis

Financial analysis plays an important role in assessing the economic viability of the project and financial plan approach. This analysis covers everything from estimating the initial investment to projecting revenues and identifying potential sources of financing.

ECONOMIC AND FINANCIAL DATA

The economic viability analysis focuses on providing an initial assessment of key financial elements essential for determining the project's feasibility. Among the primary aspects of this analysis is the prediction of the initial investment size, also known as CAPEX, which includes all costs related to implementing the clean generation technologies and associated infrastructure. This preliminary estimate can be carried out using a detailed cost breakdown method, analysing each implementation cost and applying sensitivity analysis to account for variations in equipment and labour costs. Additionally, indicative operational and maintenance costs, referred to as OPEX, which reflect the daily operation of the DH system, need to be estimated to provide a broad understanding of ongoing financial requirements.

Revenue projections are another key aspect of the analysis. These are based on analysing current and potential future tariff structures, evaluating energy rates and considering their possible evolution. A critical factor in this evaluation is the estimation of future demand, as revenues are derived from the product of demand and applicable tariffs. By projecting how energy demand might evolve over time, considering factors such as population growth, industrial activity, and policy changes, the analysis provides a more comprehensive understanding of revenue potential. While detailed revenue forecasting may occur at a later stage, high-level methods, such as evaluating historical tariff trends and demand patterns, are utilized at this phase to offer an initial overview of revenue potential.

Finally, this is a pre-feasibility analysis, so it does not go into detailed financial metrics like internal rate of return (IRR), profit and loss (P&L) statements, or fully projected cash flows, as these are addressed during the more comprehensive financial or investment plan phase, like the one carried out in the Deliverable 2.3 of the financial portfolio made by the partners on the consortium. Instead, the focus is on identifying revenue sources, estimating CAPEX and OPEX, exploring potential funding sources, and assessing the evolution of demand to refine revenue estimates.

The following stage will involve collaborating with local partners to determine specific funding strategies and conduct detailed financial modelling, ensuring a thorough understanding of the project's financial implications. In addition, different scenarios are evaluated to understand the impact of various variables on the project's viability.

FEASIBILITY OF FUNDING SOURCES AND MANAGEMENT SOLUTIONS

In this section of the economic analysis, it is necessary to focus on evaluating the feasibility of accessing different funding sources and implementing different management solutions, considering the legal and operational requirements in each DH site from each target country. Possible funding sources include debt, equity, and other potential management solutions, including the evaluation of management options such as EPC, ESC, PPA, BOO, BOT, and TOR structures. These solutions include evaluating management options such as:

- Engineering, Procurement, and Construction contracts (EPC),
- Energy Supply Contracts (ESC),
- Power Purchase Agreements (PPA),
- Build-Own-Operate models (BOO),
- Build-Operate-Transfer models (BOT),
- Transfer-Operate-Renew models (TOR).

Each operator is encouraged to select the most suitable option for their specific site and use it to build their financial model, rather than evaluating all possibilities exhaustively. This approach ensures a more focused and efficient analysis.

The selected financing model should then be evaluated to assess its technical feasibility and requirements for the investment plan. The choice of the appropriate funding source will depend on factors such as preliminary cash flows, risk profile, and expected revenues.

To achieve all the above, it is important to identify the regulatory considerations linked to each option, assessing their potential restrictions and opportunities in each country. This information will form a basis for the preparation of the financial or investment plan, ensuring its relevance to both project objectives and market conditions depending on where we are developing the case study.

To conduct financial analysis, several inputs are needed from the national partners, such as available project resources, accessibility to funding methods or the initial operational considerations. Other elements such as the cost of debt (and opening fees), or other financial evaluations will be done in later phases when the financial structure for each DH site for each country is developed. The pre-feasibility study aims to lay the groundwork for understanding the potential of these options, allowing for a country-specific approach and informing financial and operational planning at later stages.

Appendix 1: Template example

Section	Sub-section	Content
Market Analysis	Historical demand	Summary of historical energy demand in the DH site, highlighting key trends.
	Retail prices analysis	Analysis of retail energy prices, including historical and current cost trends.
	Market trends	Identification of significant trends in the district heating and energy market.
	Regulatory framework	Overview of local, national, and European regulations affecting the DH sector.
	Demand forecast	Projection of future energy demand based on data analysis and market trends.
Technical Analysis	Evaluation of existing infrastructure	Assessment of the current DH infrastructure, focusing on efficiency and capacity.
	Technologies to be used	Overview of planned technologies for decarbonization.
	Modelling and simulation with nPro	Description of modelling and simulation outcomes using the nPro tool.
	Economic and CO2 emissions impact	Analysis of the economic and environmental impact, with emphasis on CO2 emissions reduction.
Financial Analysis	Economic and financial data	Collection and analysis of financial data related to the project.
	Feasibility of funding sources	Evaluation of potential funding sources and the project's economic viability.

Appendix 2: References and Related Documents

	Reference or Related Document	Source or Link/Location
1	Low2HighDH project Grant Agreement No 101120865	Low2HighDH Project SharePoint, Reference Documents folder
2	Low2HighDH project Consortium Agreement	Low2HighDH Project SharePoint, Reference Documents folder
3	WP4 - Workshop Investment Plans, 3rd Consortium Meeting	Low2HighDH Project SharePoint, 241010_Low2HighDH_CM3 - Workshop Investment plans_VF.pptx
4	D2.2 – Technical Solutions Portfolio	Low2HighDH Project SharePoint, D2.2_Technical solutions portfolio_V1.pdf
5	D2.3 – Financial Tools Portfolio	Low2HighDH Project SharePoint, D2.3 – Financial Tools Portfolio