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D10.5 - DIGITAL SOLUTION FOR CLIMATE- PROOFING URBAN ENERGY PLANNING

Development for the application to a Real Demo Case

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MULTICLIMACT

D10.5 - DIGITAL SOLUTION FOR CLIMATE-PROOFING URBAN ENERGY PLANNING

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V3.0	25/08/25	Prefinal version ready for coordinator quality check (Changes after second Review)
V4.0	17/09/25	Final version ready for submission

Table 1 Revision table for D10.5

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Abbreviations and Acronyms

ACRONYM	DESCRIPTION
CHP	Combined Heat and Power
DH	District Heating
DHN	District Heating Network
DHW	Domestic Hot Water
DMM	District Mapping Module
DPM	District Planning Module
GUI	Graphic User Interface
KPI	Key Performance Index
H&C	Heating and Cooling
HVAC	Heating, Ventilation and Air Conditioning
PV	Photovoltaic
SECAP	Sustainable Energy and Climate Action Plan
SMM	Supply Mapping Module
GFA	Gross Floor Area
NUF	Normalized Usage Factors
EVOH	Ethyl Vinyl alcohol
PE	Polyethylene
BOQ	Bill of Quantities
PEFs	Primary Energy Factors
EPBD	Energy Performance of Buildings Directive
IPCC	Intergovernmental Panel on Climate Change
UED	Useful Energy Demand
FEC	Final Energy Consumption
PEC	Primary Energy Consumption
RES	Renewable Energy Sources
OPEX	Operational Expenditures





Executive Summary

The MULTICLIMACT project aims to develop a mainstreamed framework and a supporting tool to help public stakeholders and citizens assess the resilience of the built environment and its people at multiple scales, including buildings, urban areas, and territories, in relation to locally relevant natural and climatic hazards, as well as supply-chain disruptions. The project promotes preparedness and responsiveness across the life cycle of built assets, with a specific focus on integrating human wellbeing, health, and quality of life as essential dimensions of analysis and action. To enable resilience-enhancing interventions, MULTICLIMACT provides a toolkit of 18 reliable, easy-to-implement, and cost-effective design methods, materials, and digital solutions. These are developed through a multidisciplinary approach that brings together socio-economic, life, engineering, and climate sciences.

Within this framework, the present deliverable presents the development and application of the enhanced PLANHEAT tool, designed to support climate-proof urban energy planning. The tool has been extended with new functionalities defined in Task 4.5, including the simulation of cultural heritage buildings and electricity consumption profiles based on occupancy patterns. It is implemented as a QGIS plug-in and enables the modelling of energy demand and supply at both building and district levels.

The improved tool was applied to the Latvian demonstrator, the Riga Central Market district, to assess the scalability of building-level energy efficiency solutions. Multiple scenarios were simulated to evaluate the impact of different planning strategies from energy, environmental, economic, and social perspectives. These include the integration of UPONOR low-temperature heating systems, biomass-based district heating networks, and solar thermal collectors.

The simulations revealed that the biomass-only district heating scenario offers the highest potential for CO₂ reduction and renewable energy integration, while the UPONOR system improves distribution efficiency. Solar thermal collectors, although limited in rooftop potential, may complement broader decarbonization strategies.

Partners involved in the development and validation of this deliverable include RINA-C (tool development and simulations), REA (demo site data and audits), and KTH (decarbonization strategies). The tool has been successfully validated through real-case simulations, and short- and long-term decarbonization strategies have been drafted based on the results.

This deliverable confirms the readiness of the PLANHEAT tool to support decision-makers in designing resilient and low-carbon urban energy systems.





1. INTRODUCTION

This document represents Deliverable D10.5 of the MULTICLIMACT project and reports the activities carried out under Task 10.5, focused on the development and application of a digital solution for climate-proofing urban energy planning in a real demonstrator context. The deliverable documents the development and application of the enhanced PLANHEAT tool, implemented within the MULTICLIMACT framework, to support the simulation of energy demand, supply, and planning strategies at both building and district levels.

The improved tool has been applied to the Latvian demonstrator site—the Riga Central Market district—to investigate the scalability and impact of energy efficiency solutions initially demonstrated at building level. The focus is on assessing how these solutions perform when extended to the city scale, particularly in terms of energy, environmental, economic, and social dimensions.

The Riga demo case presents a complex urban environment with cultural heritage constraints, diverse building typologies, and an existing district heating network. These characteristics make it an ideal testbed for validating the upgraded functionalities of the PLANHEAT tool, including the modelling of historical buildings and electricity consumption profiles.

Through scenario-based simulations, the tool enables the evaluation of multiple planning configurations, supporting the development of robust decarbonization strategies. The results of these simulations provide actionable insights for local stakeholders and urban planners, contributing to the formulation of short- and long-term pathways toward climate resilience and energy transition. The document is structured into eight chapters. Chapter 1 introduces the purpose, scope, and target audience of the deliverable. Chapter 2 defines the objectives of Task 10.5, while Chapter 3 explains the overall approach adopted for tool development and validation. Chapter 4 describes the enhanced PLANHEAT tool and its new functionalities. Chapter 5 presents the application to the Riga Central Market demonstrator, including baseline analysis and scenario simulations, and Chapter 6 explores future scenarios and decarbonization strategies. Finally, Chapter 7 summarizes the main conclusions, and Chapter 8 provides the list of references.

1.1. PURPOSE AND TARGET GROUP

The purpose of this deliverable is to document the development and application of the enhanced PLANHEAT tool for climate-proof urban energy planning within the MULTICLIMACT project. It describes the new functionalities introduced to support the modelling of cultural heritage buildings and electricity consumption profiles, and their validation through the Riga Central Market demonstrator.

The document is intended for public authorities, urban planners, energy consultants, and decision-makers seeking practical and scalable solutions for integrating energy efficiency measures and renewable energy sources into urban energy systems.

1.2. CONTRIBUTIONS OF PARTNERS

Table 2 Contributions of consortium partners to D10.5

The following Table 2 *Contributions of consortium partners to D10.5* depicts the main contributions from project partners in the development of this deliverable.

PARTNER SHORT NAME	CONTRIBUTIONS
RINA-C	PlanHeat explanations, development, simulations results
REA	Contribution with Data and content regarding the Demo site
KTH	Short and Long Decarbonization Strategies, explanation of the Dairy Pavillion situation after UPONOR technology implementation





2. OBJECTIVES

The main objective of Task 10.5 is to apply and validate the enhanced functionalities of the MULTICLIMACT climate-proofing urban energy planning tool—developed during Task 4.5—within a real demonstrator context. The tool is based on PLANHEAT, an open-source GIS-based planning solution implemented as a plug-in for the QGIS desktop application. It enables simulation of energy consumption behaviour of groups of buildings in urban territories under future decarbonized scenarios, using planning criteria defined through specific Key Performance Indicators (KPIs).

The upgraded tool includes new algorithms and methodologies to support the modelling of cultural heritage buildings and electricity consumption profiles. Specifically, the District Mapping Module (DMM) has been extended to estimate hourly demand profiles for heating, cooling, and domestic hot water (DHW) in historical buildings, and to calculate electricity demand based on occupancy patterns and user behaviour.

Within this task, the tool is applied to the Latvian demonstrator—the Riga Central Market district—to investigate the scalability of building-level energy efficiency solutions to the district level. The evaluation is conducted across energy, environmental, economic, and social dimensions.

The specific objectives are:

- **Functional Validation:** test and validate the new functionalities of the PLANHEAT tool in a real-case application, focusing on cultural heritage buildings and electricity demand modelling.
- **Scenario Simulation:** simulate multiple planning scenarios based on defined targets, including the integration of renewable energy sources and efficient heating technologies.
- **Impact Assessment:** evaluate and compare the scenarios using KPIs related to energy consumption, CO₂ emissions, operational costs, and renewable energy share.
- **Strategy Formulation:** draft short-term and long-term decarbonization strategies for the Riga demo case, based on simulation results and aligned with EU climate objectives.
- **Stakeholder Support:** provide a decision-support framework for local authorities and planners to guide the implementation of resilient and low-carbon urban energy systems.

3. OVERALL APPROACH

The development of the improved PLANHEAT tool within Task 10.5 followed a structured and iterative methodology, ensuring alignment with the overarching objectives of the MULTICLIMACT project and the specific needs of the Riga demonstrator.

The approach was articulated through the following key steps:

- Strategic Alignment:** The initial phase involved a collaborative assessment among the project coordinator, WP leader, Task 4.5 leader, and involved partners to ensure that the tool development would effectively contribute to the MULTICLIMACT objectives. This included identifying how the digital solution could support climate-proof urban energy planning and decarbonization strategies.
- Tool Familiarization and Gap Analysis:** The existing PLANHEAT tool was presented and analysed to identify its baseline functionalities and limitations. This step enabled the definition of the required enhancements to address the specific characteristics of the Riga demo site, particularly the cultural heritage buildings.
- Agile Development Process:** The implementation followed an agile and modular development strategy. Functional improvements were broken down into discrete tasks, each undergoing unit and system testing to ensure robustness and consistency with the original tool architecture.
- Database and Algorithm Enhancements:** The development began with the integration of new datasets and algorithms into the PLANHEAT database. This included the creation of specific demand profiles for cultural heritage buildings and the modelling of electricity consumption based on occupancy patterns and user behaviour.





- e) **Codebase Extension:** Python scripts were developed and integrated into the existing codebase, maintaining consistency with the original coding style to ensure clarity and maintainability. Each new feature was validated through end-to-end simulations to verify its impact on the tool's performance.
- f) **Validation through Real-Case Application:** The upgraded tool was tested using data from the Dairy Pavilion of the Riga Central Market. The simulation parameters were aligned with those from the official energy audit to ensure comparability and reliability of results.
- g) **District-Level Application:** Following successful validation, the tool was applied to a broader area surrounding the market to assess the scalability of the solutions and their impact at district level.
- h) **Scenario Analysis and Strategy Development:** Multiple future scenarios were simulated, incorporating different planning criteria and technology mixes. The results informed the drafting of short- and long-term decarbonization strategies for the Riga demo case, with contributions from KTH.

4. TOOL DESCRIPTION

This section provides a comprehensive overview of the enhanced PLANHEAT tool, developed within the MULTICLIMACT project to support climate-proof urban energy planning. PLANHEAT is a GIS-based open-source desktop application implemented as a QGIS plug-in. It enables users to simulate and evaluate low-carbon heating and cooling (H&C) scenarios at urban scale, integrating energy demand mapping, supply potential assessment, and scenario planning functionalities.

4.1. PLANHEAT

The tool is structured into three core modules:

- **SMM:** maps the theoretical and technical potential of various energy sources for heating and cooling, including biomass, excess heat, geothermal, solar, and water bodies. It supports both default European datasets and user-provided local data;
- **DMM:** estimates hourly heating, cooling, and DHW demand at building level using a bottom-up approach. It supports both simplified and complete methodologies depending on data availability, and allows for retrofitting scenario definition;
- **DPM:** enables the definition and simulation of baseline and future energy scenarios. It uses output from DMM and SMM to model energy demand and supply matching, calculate KPIs, and support district heating and cooling network design.

4.2 PLANHEAT IMPLEMENTATION

As part of the MULTICLIMACT project, two major functionalities have been integrated into the PLANHEAT tool to extend its applicability and accuracy in urban energy planning:

4.1.1. ELECTRICITY CONSUMPTION

Within the MULTICLIMACT project, the PLANHEAT tool has been extended to estimate electricity consumption related to two specific end-uses: equipment and lighting. This functionality complements the existing modules for heating, cooling, and DHW, enabling a more complete representation of building energy demand.

The methodology adopted for electricity consumption estimation is consistent with the one used for DHW demand. Specifically, for each building category, a reference value of electricity consumption per square meter is assigned for both equipment and lighting. These values are then multiplied by the gross floor area of each building and modulated over time using the same occupancy-based usage profiles already implemented in the tool for DHW, also, the complete methodology has been provided in Deliverable 4.5.





The total electricity demand for each building is calculated as:

$$E_{total} = (E_{equip} + E_{lighting}) GFA \cdot NUF_{elec}$$

Where:

- E_{equip} and $E_{lighting}$ are the reference electricity consumption values (in kWh/m²/year) for equipment and lighting respectively;
- GFA is the gross floor area of the building (in m²);
- NUF_{elec} is the normalized usage factor derived from occupancy patterns and building typology [7] [8].

To support this new functionality, the planheat.db database has been extended with two new tables that store the electricity consumption references values for each building use category. These tables are linked to the existing `building_use` table through foreign keys, ensuring consistency with the existing data structure used for heating, cooling, and DHW demand estimation.

In parallel, the Python codebase of the PLANHEAT QGIS plug-in has been updated to:

- Retrieve the new electricity-related parameters from the database;
- Apply the same occupancy-based temporal modulation logic used for DHW;
- Integrate the results into the simulation pipeline and output layers.

As a result, the output shapefiles and summary csv reports generated by the tool now include additional fields for:

- Annual electricity demand for equipment and lighting (kWh/year);
- Electricity demand per square meter (kWh/m²/year);
- Hourly electricity demand profiles.

These enhancements allow users to evaluate the impact of electrification strategies, assess the contribution of lighting and appliances to total energy demand, and support the design of more comprehensive decarbonization pathways at district level.

4.1.2. HISTORICAL HERITAGE BUILDINGS

To support the simulation of historical structures such as the Riga Central Market, a new building category, Cultural Heritage Building, has been added to the PLANHEAT tool. This enhancement enables accurate modelling of energy behaviour in protected buildings, supporting the design of compatible renovation strategies and the assessment of their impact on district-level decarbonization. The implementation includes:

- Specific U-values, ventilation losses, and internal gains based on historical construction typologies;
- Tailored occupancy schedules and usage patterns derived from the Riga demonstrator;
- Integration of the inference rules used to estimate energy demand based on country, construction year, and building use;
- Compatibility with both simplified and complete assessment methodologies.

From a technical perspective, the planheat.db database has been extended with new entries and dedicated tables:

- The `building_use` table now includes the “Cultural Heritage” category;
- The tables `u_values`, `air_leakage_distribution`, and `glazing` have been populated with data specific to historical buildings, structured by country and construction year.

These datasets were derived from official reports and technical documentation provided by the City of Riga [1]. The Python codebase of the PLANHEAT plug-in has been updated to:

- Recognize the new building category during data import and mapping;
- Apply the appropriate inference rules to retrieve energy parameters from the extended database;





- Integrate the new category into both the DMM and the DPM workflows and Graphical User Interface.

As a result, the simulation outputs now include:

- Hourly heating, cooling, and DHW demand profiles specific to cultural heritage buildings;
- Differentiated results based on envelope protection levels (e.g., walls, roofs, windows);
- Enhanced scenario comparison capabilities for renovation strategies involving protected structures;
- Totalized results based on the Historical category of buildings.

These improvements ensure that the PLANHEAT tool can be effectively used in contexts where historical preservation constraints must be considered alongside energy efficiency and decarbonization goals.

To validate the assumptions and parameter values introduced in the updated database and Python codebase, the following sections will present the application of the tool to the Dairy Pavilion of the Riga Central Market. This real-case simulation will allow for a direct comparison between calculated and audited energy performance, confirming the reliability and applicability of the implemented functionalities.

5. APPLICATION TO THE REAL DEMO CASE

5.1. RIGA MARKET DESCRIPTION

Heat supply to the central market pavilions for heating and hot water consumption is provided using a district heating (DH) system which is well developed in Riga. Two types of fuel are widely used in Riga - natural gas and wood chips. In 2023, about 3,100 GWh of heat were transferred to the networks and about 2,700 GWh were consumed. Figure 1 presents the distribution of technology and fuel used in the heating network in 2023. Among renewable energy resources, biomass (wood chips) is widely used. In 2023, 41.3% of the heat was produced from biomass which corresponds to a sustainable principle according to Directive (EU) 2018/2001 of the European Parliament [9] and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (12.9% from biomass CHP and 28.4% from biomass boilers).

Technologies mix in heat production in 2023

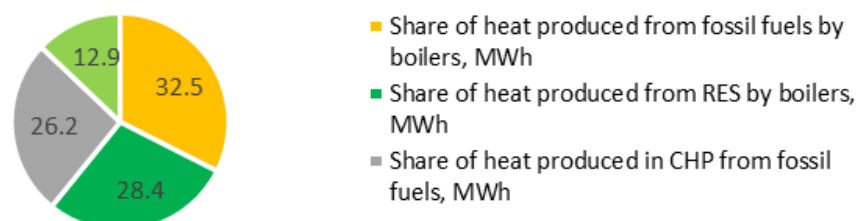


Figure 1. Technologies mix in heat production in 2023





The heat transmission network is built of pre-insulated steel pipes laid side-by-side trenchless underground. Temperature regime of 118/70 is used for heat transmission at the calculation temperature -20 °C (minus 20°C). The average statistic estimated outdoor temperature of a heating season according to the amendments of 01.05.2021 to Cabinet Regulation No. 432 “Regulations on the Latvian Building Standard LBN 003-19 “Building climatology”” equals to 1.1°C and the duration of a heating season in Riga is 192 days. The average supply temperature during the heating season is 65-67°C and returns 45°C. Heat tariffs in Riga are regulated by the Public Service Regulatory Commission and consist of three components: heat production, transmission and trade tariffs. Heat tariffs change according to the situation of the world (natural gas) and local (wood chips) energy prices. Figure 2 *Heat tariff changes over the last 10 years* shows the changes in the heat tariff in Riga over the last 10 years. In 2015, the tariff was only 45.19 EUR/MWh. When the war in Ukraine began, the price of natural gas in Europe and the Baltic States increased dramatically and the heat tariff was as high as 183.86 EUR/MWh. As the price of natural gas changed, the heat tariff decreased and is currently 74.14 EUR/MWh. But an increase in heat tariffs is planned for the new heating season from October 2025.

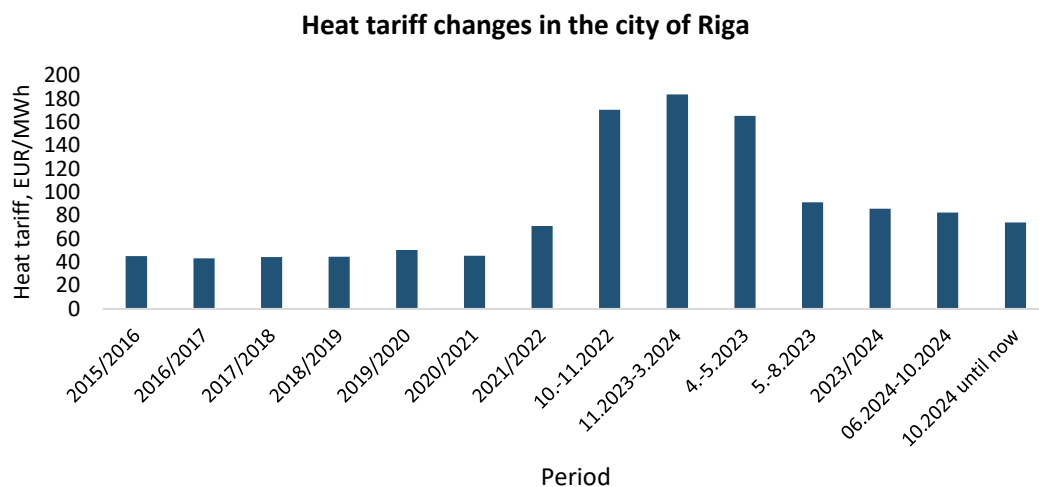


Figure 2 Heat tariff changes over the last 10 years



5.1.1. SITUATION “AS IT IS”

The Dairy pavilion of Riga central market has been chosen as a demo site in the MULTICLIMACT project. The building consists of 2 floors. The first-floor space is a large shopping hall without division into sectors or separate rooms. Two heating solutions are used currently in the Dairy pavilion: heat barrier for the influx of cold air by opening the entrance door - so-called air curtains and hot air blowers (see Figure 4: *Images of air curtains and hot air blowers*).

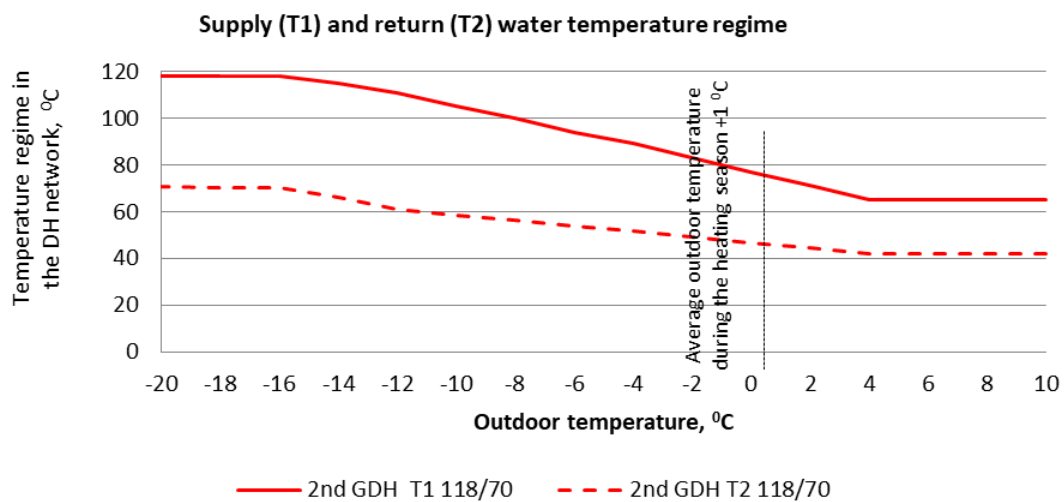


Figure 3 Temperature regime in the DH network (Second generation district heating 2nd GDH).



Figure 4: Images of air curtains and hot air blowers

Air curtains are placed at two entrance doors, while hot air blowers are placed at the same door and the entrance/exit at the gastronomy pavilion (see Figure 5 Location of air curtains and hot air blowers in the dairy pavilion building).



Figure 5 Location of air curtains and hot air blowers in the dairy pavilion building

An energy audit has been conducted for the Dairy pavilion building. During the energy audit, data was collected on heat consumption for heating, hot water, and electricity consumption.

The average annual figures are shown in Table 3 *Average historical data of energy consumption on the dairy Pavilion.*

ENERGY CONSUMPTION, MWH PER YEAR	HEATING (AVERAGE NUMBER FROM 2022 UNTIL 2024)	HOT WATER (AVERAGE NUMBER FROM 2021 UNTIL 2024)	ELECTRICITY (AVERAGE NUMBER FROM 2023 UNTIL 2024)
	56.1	26.1	136.36



Table 3 Average historical data of energy consumption on the dairy Pavilion

It should be especially emphasized that the building of the Dairy pavilion has not been used for the sale of dairy products during the reporting period. In addition to these, the Dairy pavilion was not sufficiently heated due to economic considerations. The indoor temperature during the heating season was on average +10-12°C at +2°C ambient temperature outside.

The energy audit was conducted assuming an indoor temperature of +10°C. However, using a model developed by the energy auditor, the heat consumption was also estimated for a target temperature of +16°C. The results are presented in Table 4.

INDOOR TEMPERATURE IN THE DAIRY PAVILION, °C	HEATING CONSUMPTION, KWH PER YEAR	SPECIFIC HEAT CONSUMPTION FOR HEATING, KWH/M ²
+10°C	52,168	21.8
+16°C	175,802	73.5

Table 4 Existing and modelled heat consumption for heating of a dairy pavilion at different indoor temperatures

Therefore, the heat consumption for heating of 175,802 kWh per year can be considered as a baseline. The maximum evaluated by energy auditors heating capacity, when implementing energy efficiency measures, is 198 kW, cooling capacity 86 kW.

Currently, neither a natural nor a mechanical ventilation system has been built in the pavilion. To ensure the necessary air exchange and microclimate requirements, ventilation system solutions have been planned within the framework of two separate projects. In turn, mechanical (forced) ventilation systems should be designed and later built with the funds of JSC "Rīgas nami".

To improve cooling in the Dairy pavilion, the energy auditors recommended using passive or natural ventilation through operable roof windows to remove excess heat and air pollutants from the space. JSC "Rīgas nami" has included in the reconstruction project of the roof replacement the development and implementation of a natural ventilation solution using automatically opening windows. Currently, the construction project proposal includes 24 such windows. Therefore, the installation of passive ventilation is not included in the MULTICLIMACT project.

5.1.2. SITUATION AFTER THE RENOVATION

The solution for the low-temperature heating system based on UPONOR technology is described in the following sub-chapters. The constructional improvements to the Dairy Pavilion building, including energy efficiency measures and the installation of a mechanical ventilation system, fall outside the scope of the MULTICLIMACT project and will be funded by the Riga City Municipality-owned company JSC "Rīgas nami".

5.1.2.1. Design of low temperature heating solutions

The preliminary low-temperature heating system was designed for the Riga central market pavilion (i.e., Latvian demo). Results of the energy audit and data pre-processing show that the pilot is a district-heated cultural-heritage building supplied by a centralized district-heating network. Five heat exchangers with a total installed capacity of 3,379 kW serve the complex energy system. During the design phase, we evaluated several radiant heating systems. We applied detailed modelling works to the site practical constraints—including structural limits of existing materials, shop layouts,





architectural preservation requirements, and floor-space restrictions. To respect the heritage floor build-up and embedding-depth limits, Uponor's Classic wet underfloor-heating system (Figure 6 *Uponor Classic Wet Underfloor-Heating (D9.3)*) was specified. Prefabricated, corrosion-protected steel-mesh mats clip directly onto the existing insulation, preserving the historic substrate. Uponor Comfort Pipe PLUS Blue is the state-of-the-art sustainable piping solution using renewable materials with an oxygen diffusion barrier. This barrier consists of a layer of ethyl vinyl alcohol (EVOH) extruded on the outside of the PEX pipe. The outermost layer is polyethylene (PE). This layer is very flexible and does not affect the flexibility and pliability of the basic pipe. Renewable PE raw material for the pipe is based on the Bornewables™ product range supplied by Borealis. These raw materials are made using sustainably sourced renewable feedstocks derived solely from waste and residue vegetable oils, such as used cooking oil and residues from vegetable oil processing. The residue from vegetable oil processing consists of rancid fat that must be removed to produce food-grade oil. The used cooking oil, entirely waste and residues in origin, is a waste stream collected from restaurants and the food industry. The waste and residue raw materials that are used to produce our feedstock are no longer fit for human consumption, and as such, do not impact food security. In the MULTICLIMACT project, 20x2.0 mm dimensions are selected and enable continuous circuit lengths up to 120 m without intermediate joints, efficiently covering large floor areas. Its modular design accommodates any insulation material from standard residential to heavy-duty commercial—without risking integrity. Comfort Pipe PLUS BLUE is stress-resistant and engineered for long service life, ensuring reliable, low-maintenance performance in a cultural-heritage environment.



Figure 6 Uponor Classic Wet Underfloor-Heating (D9.3)

Below are the design and calculation results for the under-floor heating system, including detailed system drawings and a preliminary bill of materials. These results will form the basis of the upcoming tender process to select the installation contractor. They will also serve as the foundation of the new BIM model, with the pipe layout to be installed in accordance with this design. Most of the materials listed in the current bill of quantities will be carried over into the new BIM. Please note that this is a preliminary bill of materials; a fully detailed and precise version will be produced once the new BIM model is complete, since some components cannot yet be quantified at this stage.



5.1.2.2. Under floor heating system design

Figure 7: *Single line diagram of the underfloor heating solution (D9.3)* shows the single-line diagram superimposed on the floor plan. Return water from the district-heating network (42–46 °C) enters a low-temperature substation where it is tempered to a 39 °C supply. From there, a main loop circulates at 37,745 kg/h through seven manifold stations (M.01–M.07) before returning at 33.8 °C. Each manifold feeds 15–19 individual circuits of 20 × 2.0 mm Comfort Pipe PLUS, maintaining continuous loop lengths for efficient heat delivery. Available pressure head on the main loop is 111.5 kPa, while individual manifold Δp values range from 66.8 kPa at M.06 to 90.0 kPa at M.05. Isolation valves, flow meters and differential-pressure gauges at each manifold ensure balanced hydraulics and streamline commissioning.

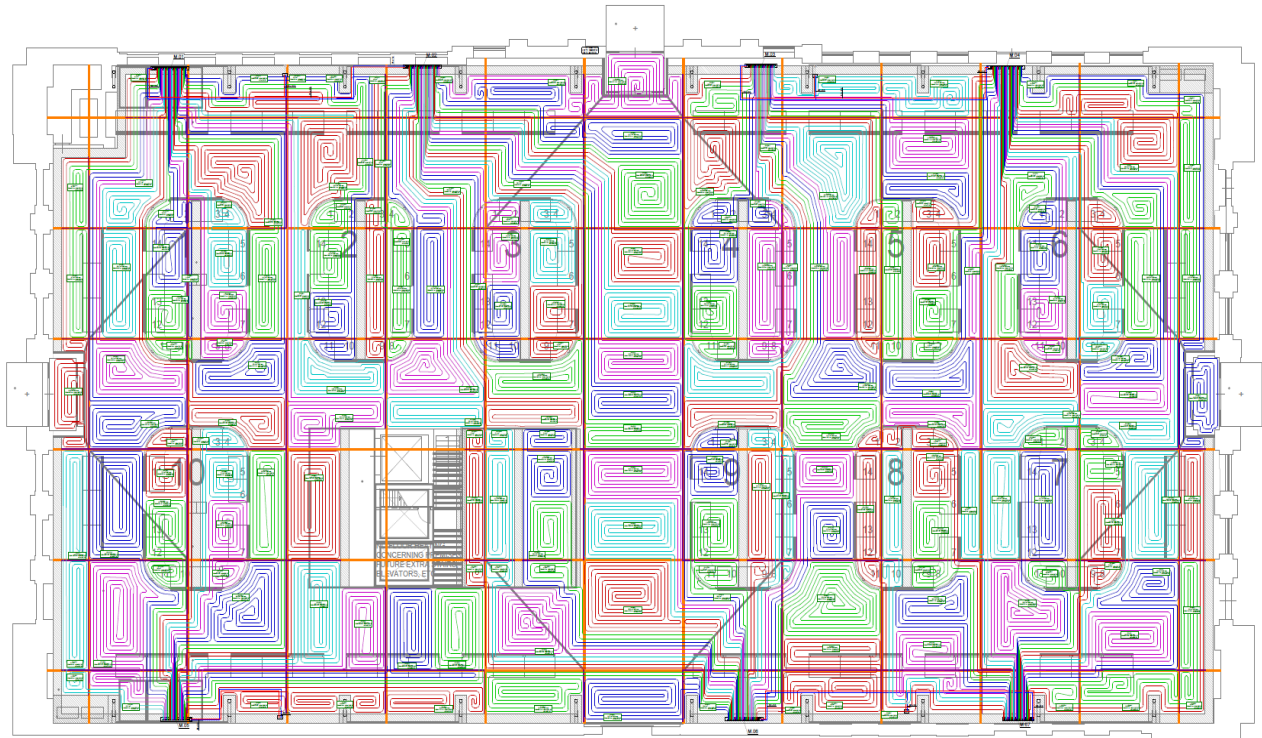


Figure 7: Single line diagram of the underfloor heating solution (D9.3)

Figure 8. *key manifold circuit parameters* summarizes, for each manifold station (M.01–M.07), the number of circuits, required versus delivered heat outputs, design ΔT (5.0–5.3 K), mass flow (4,845–6,207 kg/h), pressure drop (55.6–90.0 kPa) and total loop length (1,450–1,893 m). These data confirm that every circuit stays within the Comfort Pipe PLUS continuous-loop limits while reliably meeting the calculated thermal loads.



Source/Source: 1		Application: Heating systems/Cooling systems					Medium: Water			
Temperatures $\theta_{s,H}$ and $\theta_{r,H}$ [°C]		39.0					33.8			
Temperature source for control circuitSource / 1										
Temperatures $\theta_{s,H}$ and $\theta_{r,H}$ [°C]		39.0					33.8			
Required heating output $\Phi_{req,H}$ [W]		199532								
Obtained heating output Φ_H [W]		207643								
Heat capacity lost $\Phi_{OS,H}$ [W]		12837								
Mass flow rate m [kg/h]		37887.5								
Manifold symbol	Storey symbol	Number of heating/cooling circuits	Obtained output of heat./cool. zone (heating mode)	Output lost of heat./cool. zone (heating mode)	Return temperature on manifold (heating mode)	Temperature difference on manifold (heating mode)	Mass flow rate	Required min. pressure difference	Resultant pressure difference	Total pipe length in loop systems
Manifold	Stor.	N	Φ_H W	$\Phi_{OS,H}$ W	$\theta_{r,H}$ °C	$\Delta\theta_H$ K	m kg/h	Δp_{min} kPa	Δp kPa	Ltot m
M.01	0	18	32365	1996	33.7	5.2	5784.6	68.7	79.2	1801.9
M.02	0	19	33640	2083	33.9	5.1	6207.3	74.0	82.7	1893.3
M.03	0	15	26337	1594	33.9	5.1	4753.3	55.6	71.4	1455.4
M.04	0	18	28991	1828	34.0	5.0	5509.6	64.1	68.0	1698.5
M.05	0	15	27986	1729	33.7	5.3	4972.4	59.5	90.0	1532.2
M.06	0	18	31066	1919	33.9	5.1	5673.2	66.8	66.8	1774.3
M.07	0	16	27259	1687	33.9	5.1	4845.6	58.1	69.6	1520.8

Figure 8. key manifold circuit parameters

5.1.2.3. Bill of quantities

The bill of quantities (BOQ) specifies all Uponor components required for the Classic wet under-floor-heating installation. It includes: 11,677 m of 20 × 2.0 mm Comfort Pipe PLUS PE-Xa loops and 2,257 m² of corrosion-protected steel-mesh mats in 50 mm, 100 mm and 150 mm grid patterns; seven complete manifold assemblies paired with 416 m of MLC distribution piping; and 476 m of Magna expansion-protective pipe to accommodate thermal movement. In addition, the BOQ provides 23554 master-clips, cable ties and screed accessories to secure the circuits, plus dedicated mounting brackets for each manifold. Below is the full breakdown of BOQ items. Please note that this is a preliminary bill of materials; a fully detailed and precise version will be produced once the new BIM model is complete, since some components cannot yet be quantified at this stage.

At position A (Figure 9. *Underfloor heating manifold with vario actuators and Uponor's matrix controls*) the manifold feeds multiple underfloor heating circuits, each regulated by a Vario Actuator NC FT 24 V for precise loop-by-loop temperature control. Position B houses the Uponor Smatrix Base PRO Controller X-147 Bus together with the Smatrix PULSE Com R-208 communication module and the Uponor Smatrix Base PULSE controller, enabling wireless coordination across all zones. At position C the wall-mounted Uponor Smatrix Base digital thermostat integrates relative-humidity and operative-temperature sensing to fine-tune setpoints. This configuration delivers accurate, energy-efficient management of the underfloor heating system.

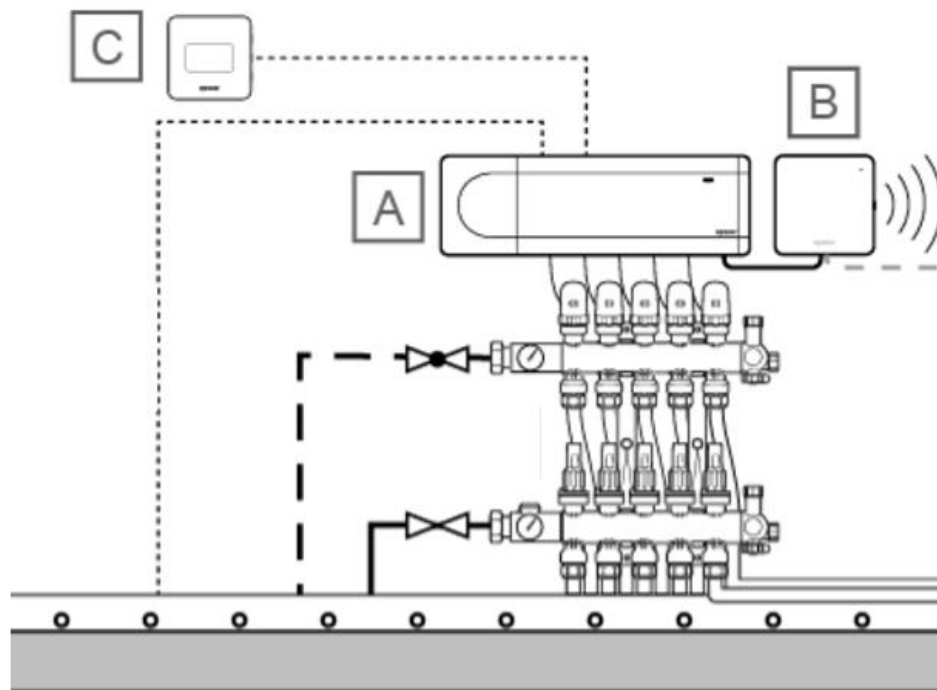


Figure 9. Underfloor heating manifold with vario actuators and Uponor's matrix controls

5.2. SCENARIOS DEFINITION

In order to evaluate the impact of different energy planning strategies on the Riga Central Market area, a set of simulation scenarios has been defined and implemented within the PLANHEAT tool. These scenarios aim to reflect both the current configuration of the district and potential future developments, including the integration of renewable energy sources, energy efficiency measures, and innovative technologies. Although the main focus of this chapter is on technical and environmental aspects, social considerations have been integrated into the analysis through specific modelling assumptions. In particular, the preservation of cultural heritage has been ensured by excluding invasive retrofit measures such as window replacement or additional insulation layers, while future scenarios maintain stricter indoor comfort constraints compared to the current situation to guarantee usability and an improved experience for occupants in these public spaces. These elements, although not extensively detailed in the following sections, represent key factors for ensuring the acceptability and long-term sustainability of the proposed solutions.

The simulation focuses on the Dairy Pavilion as the reference building and extends to a selected group of surrounding buildings to assess the scalability of the solutions at district level. Each building in the simulation has been characterised according to the PLANHEAT workflow, assigning specific technologies to cover heating, cooling, and DHW demand.

Figure 10. Map representation of the Riga Central Market Area below shows the spatial configuration of the simulation area, as implemented in the PLANHEAT environment:

- Yellow: the Dairy Pavilion, which serves as the main demonstrator building.
- Orange: additional buildings (100) representing the whole Riga Central market area included in the simulation to evaluate the scalability of the solutions.
- Green: the district area considered for strategic planning and scenario analysis.



This visual representation reflects the shapefiles imported into the tool and used to define the simulation perimeter and building typologies. Each building polygon has been linked to its corresponding energy demand profile and technology configuration.



Figure 10. Map representation of the Riga Central Market Area

To support the simulation of different energy planning strategies in the Riga Central Market area, the PLANHEAT tool provides a structured interface for configuring the technological setup of each building. The figure below illustrates the technology characterization panel within the DPM, where users can define the heating, cooling, and DHW systems for each building.

Cooling	Heating	Domestic Hot Water
Technology Air source compression chiller	Technology Gas Boiler	Technology Biomass Boiler
Tilt angle [°] 1.00	Tilt angle [°] 1.00	Tilt angle [°] 1.00
Supply T [°C] 1.00	Supply T [°C] 1.00	Supply T [°C] 1.00
Efficiency [-] 1.00	Efficiency [-] 0.90	Efficiency [-] 0.90
1st order coeff 3.10	1st order coeff 3.10	1st order coeff 3.10
2nd order coeff 0.0005	2nd order coeff 0.0005	2nd order coeff 0.0005
El. sale [€/kWh] 1.00	El. sale [€/kWh] 1.00	El. sale [€/kWh] 1.00
P_Max [kW] 1.00	P_Max [kW] 1.00	P_Max [kW] 1.00
P_Min [kW] 1.00	P_Min [kW] 1.00	P_Min [kW] 1.00
Power-to-heat ratio [-] 1.00	Power-to-heat ratio [-] 1.00	Power-to-heat ratio [-] 1.00
Technical Minimum [-] 0.00	Technical Minimum [-] 0.00	Technical Minimum [-] 0.00
Ramp Up/Down [%] 100.00	Ramp Up/Down [%] 100.00	Ramp Up/Down [%] 100.00
Fixed Cost [€/kW] 1.000	Fixed Cost [€/kW] 1.000	Fixed Cost [€/kW] 1.000
Fuel Cost [€/kWh] 1.000	Fuel Cost [€/kWh] 1.000	Fuel Cost [€/kWh] 1.000
Var Cost [€/kWh] 1.000	Var Cost [€/kWh] 1.000	Var Cost [€/kWh] 1.000
TES_size [kWh] 1.00	TES_size [kWh] 1.00	TES_size [kWh] 1.00
SOC_min [-] 1.00	SOC_min [-] 1.00	SOC_min [-] 1.00
TES_start_end [-] 1.00	TES_start_end [-] 1.00	TES_start_end [-] 1.00
TES charge/discharge time [h] 1.00	TES charge time [h] 1.00	TES charge time [h] 1.00
eta_absorption [-] 1.00	TES loss [%/w] 0.000	TES loss [%/w] 0.000
eta_absorption [-] 1.00	eta_absorption [-] 1.00	eta_absorption [-] 1.00
Remove Technologies	Remove Technologies	Remove Technologies
Apply	Apply	Apply

Figure 11 Technology configuration interface in PLANHEAT

This interface shown above in Figure 11 *Technology configuration interface in PLANHEAT* allows users to assign specific technologies to each energy vector (heating, cooling, DHW), define their installed



power, efficiency, and associated energy prices. These parameters are essential for simulating realistic energy scenarios and evaluating their technical and economic performance.

The following sub-sections describe how these options have been used to model the Riga Central Market district:

- **Section 5.2.1** details the modelling of the district heating system, including the allocation of power between gas and biomass sources.
- **Section 5.2.2** explains the methodology used to assign realistic efficiency values to each technology, considering generation, distribution, and building-level performance.
- **Section 5.2.3** presents the local electricity and heat prices used in the simulations, the Primary Energy Factors and the Emissions Factors which are critical for computing cost-related KPIs.

5.2.1. POWER OF BIOMASS AND GAS SYSTEM

The Riga district heating network supplies thermal energy to the Central Market area through a combination of gas-based combined heat and power (CHP) and biomass boilers. Based on the Riga SECAP documentation and local stakeholder input, the energy mix is assumed to be composed of 60% gas and 40% biomass.

Due to the current structure of the PLANHEAT tool, which allows only one technology per energy vector per building, the following modelling strategy has been adopted:

	Primary energy factor	CO ₂ Emission factor	NO _x Emission factor	SO _x Emission factor	PM ₁₀ Emission factor
Biomass Forestry	1	403.2	4.29	1	1
Natural gas	1	201.96	0.107	1	1
Electricity	1	1	1	1	1
Heating Oil	1	266.76	0.644	1	1
Coal and Peat	1	353.88	1.609	1	1

Figure 12 PEF and CO₂ Emission factor configuration table in PLANHEAT

- Each building is assigned two parallel heating technologies within the DPM:
 - Gas Boiler (covering 60% of the peak thermal demand)
 - Biomass Boiler (covering 40% of the peak thermal demand)

This approach ensures that the district-level energy mix is respected while maintaining compatibility with the tool's internal logic. The peak power assigned to each technology is calculated as a percentage of the building's total heating demand, as estimated by the District Mapping Module.

5.2.2. EFFICIENCY OF THE TECHNOLOGIES

To ensure realistic simulation results within the PLANHEAT environment, each heating technology has been characterized by a comprehensive total efficiency value. This value reflects the entire chain of energy transformations, from generation to final use, and is essential for accurately modelling the energy performance of the Riga Central Market district.

The total system efficiency is calculated by combining the following four layers:

- **Plant Efficiency (η_{plant})**
This represents the efficiency of the gas or biomass plants used to generate heat for the district heating network (DHN). Based on the SECAP Riga documentation and data from "AS Rīgas siltums", the average plant efficiency is assumed to be 99%. [2]
- **DHN Distribution Efficiency ($\eta_{distribution\ DHN}$)**
This accounts for seasonal average performance of the DHN, including pipe losses and temperature drops. According to Table 8.1 of the SECAP document, the DHN distribution efficiency is 88.23%. [2]





- **Heat Exchanger Efficiency ($\eta_{HE\ DHN}$)**
This includes the performance of internal heat exchangers, distribution systems, and terminal units. For the Dairy Pavilion, which uses water-to-water heat exchangers, an average efficiency of 85% is assumed, based on literature values (e.g., Opadokun & Tao, 2024 [3] and Rossi et al. [6]).
- **Building Distribution System Efficiency ($\eta_{building\ system}$)**
This reflects the effectiveness of the internal heating distribution system. For the baseline scenario, the system consists of hot air blowers (Volkano), with a thermal effectiveness of 80%. Air curtains are excluded from the efficiency calculation, as their primary function is to reduce heat losses at entrances rather than directly heat the space. [4]

The total efficiency for the baseline scenario is therefore calculated as:

$$\eta_{total}^{baseline} = \eta_{plant} \cdot \eta_{distribution\ DHN} \cdot \eta_{HE\ DHN} \cdot \eta_{building\ system} = 0.99 \cdot 0.882 \cdot 0.85 \cdot 0.8 = 0.593$$

In the future scenario, the UPONOR underfloor heating system is introduced. According to the manufacturer, this system can achieve up to 20% energy savings compared to traditional heating distribution systems. [5]

This improvement is applied to the building distribution system efficiency:

$$\eta_{building\ system+UPONOR} = \eta_{building\ system} \cdot (120\%) = 0.96$$

The resulting total efficiency becomes:

$$\begin{aligned} \eta_{total}^{UPONOR} &= \eta_{plant} \cdot \eta_{distribution\ DHN} \cdot \eta_{HE\ DHN} \cdot \eta_{building\ system+UPONOR} = \\ &= 0.99 \cdot 0.882 \cdot 0.85 \cdot 0.96 = 0.722 \end{aligned}$$

These efficiency values have been truncated to second decimal number and manually entered into the PLANHEAT District Planning Module for each building. These form the basis for evaluating the energy performance of both the current and future configurations of the Riga Central Market district, enabling a robust comparison of decarbonization strategies.

5.2.3. ELECTRICITY AND HEAT PRICES

The economic evaluation of each scenario is based on local energy prices provided by the Riga Municipality. These prices have been integrated into the PLANHEAT tool to compute cost-related KPIs and assess the economic viability of each configuration.

Importantly, the heat tariff applied by the DHN operator in Riga does not vary depending on the energy source used for heat generation. Whether the heat is produced from natural gas or biomass, the final price charged to consumers remains the same, as the DHN company incorporates all production costs into a single unified tariff.

However, data provided by the Riga Municipality indicates that biomass as a raw material is potentially less expensive than natural gas, suggesting that a shift toward biomass could reduce production costs at system level.

The following Table 5 *Resources Tariffs* summarizes the energy prices used in the simulation:

SOURCE	TARIFF [€/KWH]
Electricity	0.14





Heat from DHN	0.074
Natural Gas Resource for the DHN	0.048
Biomass Resource for the DHN	0.035

Table 5 Resources Tariffs

These values have been entered in the DPM interface under the economic parameters section for each technology. They are used to compute:

- Annual energy cost per building
- Cost per unit of useful energy delivered
- Comparative cost-effectiveness of each scenario

Additionally, the PLANHEAT tool prioritizes the use of less expensive technologies first, followed by others, based on the input cost parameters.

To support the environmental evaluation of each scenario, the following Primary Energy Factors (PEFs) and CO₂ Emission Factors have been used. These values are based on Latvian national legislation and technical guidelines aligned with EPBD requirements, as well as the SECAP provided by the Riga Municipality [2].

Table 6 Primary Energy Factors and CO₂ Emission Factors

SOURCE	PRIMARY ENERGY FACTOR	CO ₂ EMISSION FACTOR
Natural Gas	1.1	0.202 tCO ₂ /MWh
Biomass	1.0	0.02 tCO ₂ /MWh
Electricity	2.4	0.109 tCO ₂ /MWh

Solid biomass (e.g., firewood, pellets, wood chips) used in Riga is generally considered carbon neutral in terms of direct CO₂ emissions, as the carbon released during combustion is offset by the carbon absorbed during biomass growth. However, lifecycle emissions from harvesting, processing, transport, and combustion inefficiencies mean that the total impact is not zero. Therefore, an emission factor of 0.02 tCO₂/MWh is adopted as a prudent estimate, consistent with IPCC guidelines and international lifecycle assessment studies.

These values have been entered in the PLANHEAT interface under the environmental parameters section and are used to compute:

- Total and specific CO₂ emissions
- Renewable vs. conventional energy shares
- Environmental KPIs for each scenario

5.3. SIMULATION RESULTS

This section presents the results of the simulations performed using the enhanced PLANHEAT tool on the Riga Central Market district. The objective is to validate the tool's new functionalities, particularly those related to historical heritage buildings, and to assess the current energy performance of the area under study. The simulations focus on the Dairy Pavilion as the main demonstrator and extend to a selected group of surrounding buildings to evaluate the scalability of the solutions at district level.





The results are structured in two parts:

- **Section 5.3.1** focuses on the validation of the tool through a comparison between simulated and audited energy performance of the Dairy Pavilion.
- **Section 5.3.2** presents the baseline energy demand of the entire district, including spatial and temporal analyses of heating, cooling, DHW, and electricity consumption.
- **Section 5.3.3** goes forward compared to the previous section, based on the results of the previous section and adding the necessary data regarding the technologies used in the district and the parameters that can be applied to this situation brings new insights regarding environmental and energy KPIs

These outputs provide a comprehensive understanding of the district's energy profile and serve as a reference for evaluating the impact of future renovation and decarbonization strategies.

5.3.1. PLANHEAT TESTING

To validate the implementation of the new functionalities in PLANHEAT, particularly those related to historical heritage buildings, the Dairy Pavilion of the Riga Central Market was selected as the reference case. This building represents a typical cultural heritage structure and is part of the district covered by the Riga DHN.

The simulation was carried out using input parameters derived directly from the official energy audit, ensuring consistency and comparability between the simulated and real-world performance. The following Table 7 summarizes the key parameters used:

PARAMETER NAME	VALUE AND UNIT OF MEASURE
Set point Temperature Winter	10°C
Set point Temperature Summer	27°C
Overall Thermal Transmittance (Walls)	0.58 W/m ² K
Overall Thermal Transmittance (Windows)	2.4 W/m ² K
Air pressure test (n ₅₀)	0.8

Table 7 Parameters of the Dairy Pavillion used in the PlanHeat simulation

These values have been manually entered into the PLANHEAT database and used by the District Mapping Module to generate hourly demand profiles for heating, cooling, and DHW.

The simulation results were then compared with the audited energy performance data provided by the City of Riga. The comparison graph below illustrates the alignment between the simulated and measured energy demand, confirming the reliability of the PLANHEAT tool in modelling historical buildings.



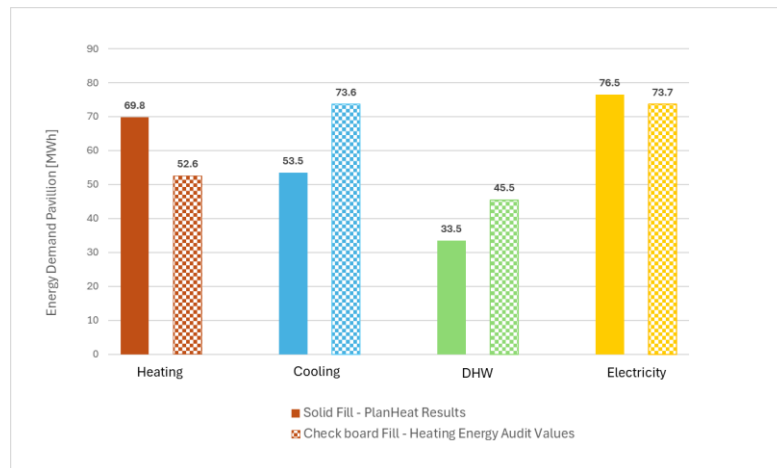


Figure 13 Results comparison between Planheat simulation and Energy Audit values

This validation step demonstrates that the enhanced PLANHEAT tool can accurately simulate the energy behaviour of protected structures, supporting informed decision-making for renovation strategies and district-level planning.

5.3.2. BASELINE RESULTS

The baseline simulation of the Riga Central Market district was conducted using the enhanced PLANHEAT tool, focusing on the current energy demand of the Dairy Pavilion and surrounding buildings. The objective was to assess the spatial and temporal distribution of energy needs across the district and to establish a reference scenario for future comparisons. The simulation that will follow from now on are entirely based on the data available on the PLANHEAT database without other changes rather than the set point winter temperature of 16°C.

5.3.2.1. Spatial Distribution of Energy Demand

The following maps (Figure 14 *Annual Heating Demand per Building* and Figure 15 *Annual Cooling Demand per Building*) illustrate the annual heating and cooling energy demand per building, as calculated by the DMM. Each building polygon is colour-coded according to its specific energy

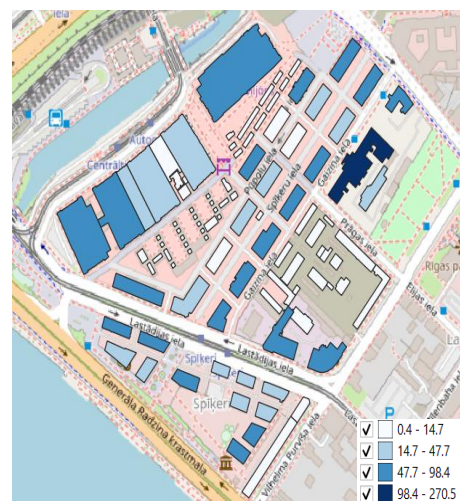
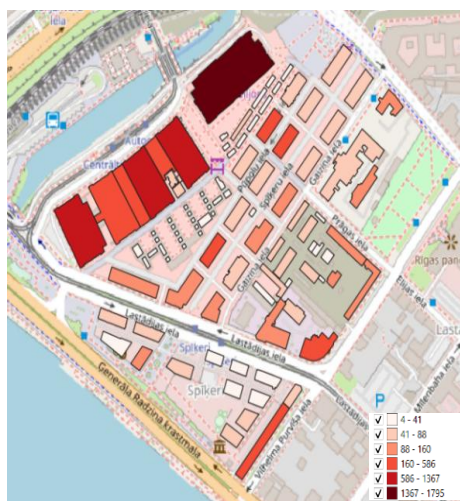


Figure 14 Annual Heating Demand per Building Figure 15 Annual Cooling Demand per Building



intensity, allowing for a clear identification of high-demand structures and potential hotspots for intervention.

These maps highlight the variability in energy needs across the district, influenced by building typology, usage patterns, and envelope characteristics. The different Market Pavilions, as expected, show distinct demand profiles due to its heritage status and specific operational schedule.

5.3.2.2. Temporal Behavior of Energy Demand

To better understand seasonal dynamics, the following graph (Figure 16 *Annual Heating and Cooling Demand Profile (MWh/hour)*) presents the hourly heating and cooling demand aggregated at district level over the course of one year:

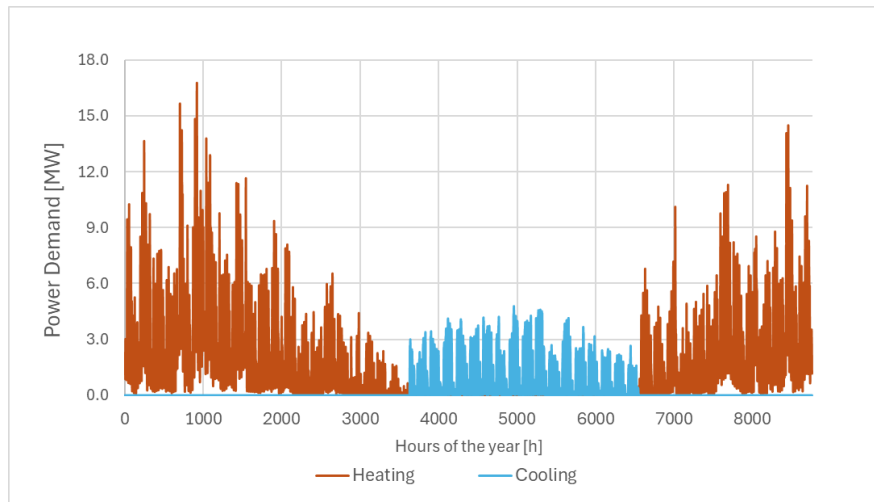


Figure 16 Annual Heating and Cooling Demand Profile (MWh/hour)

As expected, heating demand peaks during the winter months, while cooling demand becomes significant in the summer, reflecting the climatic conditions of Riga. These trends are essential for evaluating the adequacy and responsiveness of the district heating and cooling infrastructure.

It is important to note that DHW and electricity demand profiles are not shown in this graph, as their behaviour is assumed to be relatively constant throughout the year. This assumption is based on the typical usage patterns of domestic hot water and electrical appliances, which are less influenced by seasonal variations and more by occupancy schedules.



5.3.2.3. Energy Demand Breakdown by End-uses

The final chart summarizes the total annual energy demand of the district, disaggregated by energy vector: heating, cooling, DHW, and electricity. This breakdown was generated under baseline assumptions and reflects the current configuration of the district.

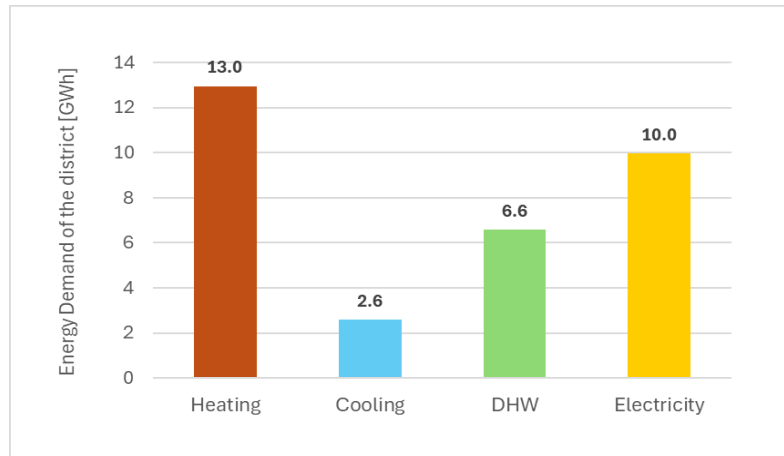


Figure 17 Total Annual Energy Demand by End-Use (GWh/year)

These total values can be compared with the figures reported in the SECAP documentation [2]. According to Table 8.1 of the referenced document, the total amount of heat energy delivered to consumers is 1,006 GWh/year, distributed across 7,532 connected sites. This corresponds to an average delivery of approximately 0.13 GWh/year per site.

In the PLANHEAT simulation, the study area includes 100 buildings, which would result in a total average heat delivery of 13.3 GWh/year. This value aligns closely with the 13 GWh/year shown in Figure 17 *Total Annual Energy Demand by End-Use (GWh/year)*, confirming the consistency of the simulation results.

Even when considering that domestic hot water demand is also supplied by the district heating network, such as in the case of the Dairy Pavilion, the results remain coherent and acceptable, especially when accounting for the inherent uncertainties in the input data and modelling assumptions used in the simulation.

5.3.2.4. District-Level KPIs

Following the characterization of the technologies assigned to each building to meet heating and DHW demand, the district-level Key Performance Indicators (KPIs) have been computed using the PLANHEAT tool. To improve the readability and visual clarity of the results, the numerical outputs are presented in tabular format Table 8 *Baseline KPIs results*) rather than as screenshots from the software interface.

PLANHEAT ID KPI	KPI COMPLETE NAME	UNIT OF MEASURE	VALUE
EN_1	Primary energy consumption baseline	MWh/year	47,863.9
	Specific primary energy consumption baseline	MWh/m ² year	0.18
EN_2	Final energy consumption baseline	MWh/year	32,910.8
	Specific final energy consumption baseline	MWh/m ² year	0.12



EN_3	Useful energy demand baseline	MWh/year	23,497.4
	Specific useful energy demand baseline	MWh/m ² year	0.09
EN_4	Primary energy consumption from RES baseline	MWh/year	12,755.8
	RES % baseline	%	26.7
EN_6	Primary energy consumption from Conventional Fuels baseline	MWh/year	35,107.2
	CFs % baseline	%	73.3
EN_9	Cooling share baseline	%	0
EN_11	FEC Solar thermal Baseline	MWh/year	0
ENV_1	CO ₂ emissions baseline	tCO ₂ /year	3,400.95
	Specific CO ₂ emissions baseline	tCO ₂ kWh (EN1) year	0.071
ECO_2.1	Baseline OPEX	M€/ year	1.69
	Baseline OPEX (+ Lighting and Equipment)	M€/ year	3.08

Table 8 Baseline KPIs results

- **Renewable Energy Classification:** Within the current configuration of the PLANHEAT tool, only biomass is classified as a renewable energy source. Electricity is treated as non-renewable, regardless of its origin. This limitation may lead to an underestimation of the renewable share in districts where electricity is partially or fully sourced from renewables. This represents an open point for future development of the tool, particularly in the context of evolving national energy mixes and EU taxonomy updates.
- **Electricity for Lighting and Equipment:** Electricity consumption for lighting and equipment is not included in the Useful Energy Demand (UED). However, it is accounted for starting from the Final Energy Consumption (FEC) level onward. This distinction is important when interpreting the KPIs, as it affects the total energy balance and the economic evaluation of the district. Future versions of the tool could benefit from integrating these end-uses into the UED calculation to provide a more complete representation of building energy needs.
- **Renewable Share in Primary Energy Consumption:** It is important to highlight that the share of primary energy consumption based on renewable energy sources is only 26.7%, which is notably low compared to the 40% share of biomass used for the DHN. This discrepancy is directly linked to the fact that, as previously mentioned, electricity is not considered renewable within the current configuration of the PLANHEAT tool unless explicitly imposed. Moreover, electricity has a significantly higher PEF compared to biomass, which further amplifies its impact on the district's overall Primary Energy Consumption (PEC). In fact, approximately 50% of the total PEC is attributed to electricity. This underscores the need for future updates of the tool to better reflect evolving national energy mixes and the EU taxonomy framework.
- **Economic Evaluation - OPEX:** The KPI ECO_2.1, which represents the baseline operational expenditure, does not account for the cost of electricity used for lighting and equipment. To address this gap, an additional row has been manually added to reflect the total OPEX, including lighting and equipment, based on an electricity price of 0.14€/kWh as indicated in previous chapters.





6. FUTURE SCENARIO

In this chapter, the focus shifts from the baseline assessment to the exploration of future energy planning strategies for the Riga Central Market district. The aim is to evaluate how technological upgrades and the integration of renewable energy sources can contribute to decarbonization, improved energy efficiency, and reduced operational costs. The simulations presented here build upon the validated baseline and leverage the enhanced functionalities of the PLANHEAT tool to model realistic and impactful future configurations.

6.1. SCENARIOS DEFINITION AND RENEWABLE POTENTIAL ASSESSMENT

In the future scenarios, the UPONOR heating technology is assumed to be applied across all buildings in the district. This upgrade leads to a significant improvement in the heating system efficiency at the building level, which is expected to reduce both final and primary energy consumption.

To further enhance the district's energy performance, the scenarios also investigate the availability and integration of renewable energy sources (RES), with the goal of increasing the RES share and reducing the reliance on conventional fuels. A higher system efficiency, combined with a greater share of renewables, is anticipated to lower the district's overall primary energy consumption and CO₂ emissions. In some configurations, this may also result in reduced operational expenditures.

To support this strategic direction, the renewable energy potential of the area is first assessed. Specifically, the analysis focuses on biomass and solar thermal resources, both of which are evaluated using the SMM of the PLANHEAT tool. For biomass, the evaluation considers a radius of 20 km around the district's location, ensuring a realistic estimation of locally available resources.

The estimations are based on two European datasets:

- **Corine Land Cover** for biomass availability;
- **PVGIS** for solar radiation data.

The production efficiency values used in the simulations are embedded in the original PLANHEAT codebase. For biomass, these vary by country, while for solar thermal, they depend on the 50x50 m grid block in which the rooftop is located. The centroid of each block is used to query PVGIS for solar energy values, to which a 40% efficiency factor is applied to account for the limited usable rooftop area. Standard technology-specific efficiency values are then applied to both resources to estimate their usable energy potential.

The graphical outputs of the PLANHEAT tool are shown in Figure 18 *Biomass availability (green: forestry, yellow: agriculture) and rooftop solar thermal potential*, illustrating the spatial distribution of renewable energy potential across the district. Table 8 *Baseline KPIs results* accompanying the figures presents the complete quantitative values for each resource type.





The methodology used for estimating renewable energy potential is consistent with the original PLANHEAT project framework and is described in detail in the corresponding PLANHEAT deliverables. This ensures methodological continuity and reliability in the simulation results presented here.

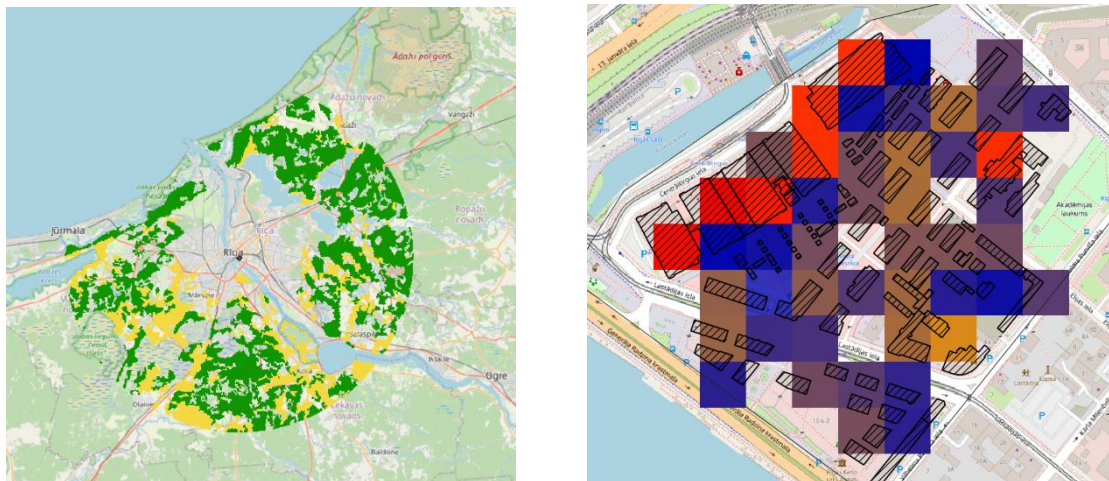


Figure 18 Biomass availability (green: forestry, yellow: agriculture) and rooftop solar thermal potential

RENEWABLE ENERGY SOURCE	VALUE AND UNIT OF MEASURE
Biomass (Agriculture)	104.3 MWh
Biomass (Broad-leaved forest)	135.3 MWh
Biomass (Coniferous)	139.5 MWh
Biomass (Forestry mixed)	523.9 MWh
Solar Thermal (Rooftops)	5.76 MWh

Table 9 Estimated renewable energy potential in the district

The results presented in the table confirm that the Riga Central Market district has access to a moderate but meaningful amount of renewable energy resources. Biomass, particularly from mixed forestry areas, shows the highest potential, while agricultural biomass and rooftop solar thermal offer additional contributions. However, when compared to the district's baseline energy needs, these quantities appear insufficient to substantially increase the RES share under realistic conditions.

For this reason, in the upcoming simulation scenarios, certain simplifications are introduced. Specifically, in the case of a hypothetical transition to a 100% district heating network based on biomass, the limitation of biomass availability within the 20 km radius around the district is not applied. Instead, it is assumed that sufficient biomass is available, in order to explore the potential energy and environmental impacts of such a configuration.

As for solar thermal, it is important to note that only rooftop areas have been considered in the assessment, which inherently limits the total potential. These assumptions allow for a more flexible evaluation of future strategies, while still being grounded in the spatial and technical constraints identified through the PLANHEAT tool.



6.2. SIMULATION RESULTS

This chapter presents the simulation results of future energy planning strategies applied to the Riga Central Market district, leveraging the enhanced functionalities of the PLANHEAT tool. Building upon the validated baseline scenario, the simulations explore the impact of technological upgrades—particularly the integration of UPONOR low-temperature heating systems—and the adoption of renewable energy sources such as biomass and solar thermal collectors.

Rather than representing definitive planning options, each scenario has been constructed as a feasibility study, aimed at providing a comprehensive overview of the potential improvements and strategic directions that the city of Riga could pursue in the energy domain. These simulations serve as a decision-support tool, helping stakeholders understand the implications of different configurations in terms of energy efficiency, environmental impact, and economic performance.

The PLANHEAT tool computes a comprehensive set of KPIs for each scenario, including primary energy consumption, final energy consumption, useful energy demand, renewable energy share, CO₂ and NO_x emissions, and operational expenditures (OPEX). These KPIs are then compared against the baseline to highlight the benefits and limitations of each strategy.

The results provide actionable insights for decision-makers and urban planners, supporting the development of robust decarbonization pathways for the Riga Central Market district. They also demonstrate the capability of the PLANHEAT tool to simulate complex urban energy systems and evaluate the effectiveness of climate-proofing interventions.

6.2.1. UPONOR SOLUTION

The UPONOR Solution Heating System scenario evaluates the district-wide implementation of UPONOR low-temperature heating technology in the Riga Central Market area. Originally designed for the Dairy Pavilion, this system is extended to all buildings in the district to simulate its potential benefits in terms of energy efficiency and emission reduction.

PLANHEAT ID KPI	KPI COMPLETE NAME	UNIT OF MEASURE	VALUE
EN_1	Primary energy consumption	MWh/year	42,697.15
	Specific primary energy consumption	MWh/m ² year	0.16
EN_2	Final energy consumption	MWh/year	27,940.05
	Specific final energy consumption	MWh/m ² year	0.11
EN_3	Useful energy demand	MWh/year	23,497.4
	Specific useful energy demand	MWh/m ² year	0.09
EN_4	Primary energy consumption from RES	MWh/year	10,452.67
	RES share	%	24.5
EN_6	Primary energy consumption from Conventional Fuels	MWh/year	32,244.48
	Conventional Fuels share	%	75.5
EN_9	Cooling share PEC	%	0





EN_11	FEC Solar thermal	MWh/year	0
ENV_1	CO ₂ emissions	tCO ₂ /year	3,268.43
	Specific CO ₂ emissions	tCO ₂ / kWh (EN1) year	0.076
ECO_2.1	OPEX	M€/ year	1.33
	OPEX (+ Lighting and Equipment)	M€/ year	2.73

Table 10 KPIs Uponor Solution Scenario

The adoption of the UPONOR system leads to a reduction in primary energy consumption and CO₂ emissions, primarily due to improved heating system efficiency (Table 10). However, the overall impact on energy demand is limited, as the technology affects only the heating vector and does not influence DHW, electricity, or cooling. The renewable energy share decreases slightly due to reduced influence of the heating consumption on the overall PEC. This scenario demonstrates that efficient technologies can play a key role in decarbonization when integrated with complementary measures.

6.2.2. BIOMASS-ONLY DISTRICT HEATING NETWORK

The Biomass-only DHN scenario explores the feasibility of supplying the entire district heating network of the Riga Central Market exclusively with biomass. This configuration aims to eliminate the use of natural gas, supporting the city's decarbonization goals and aligning with EU renewable energy directives. In this scenario, the UPONOR low-temperature heating system is also adopted across all buildings in the district, enhancing the overall efficiency of heat distribution and complementing the shift to renewable energy sources.

To reflect the lower cost of biomass compared to natural gas, the DHN tariff used in the simulation has been adjusted. While the baseline scenario assumes a unified DHN price of 0.074 €/kWh, the biomass-only configuration applies a reduced tariff of 0.054 €/kWh. This value was derived by proportionally scaling the baseline price according to the ratio between the resource costs of biomass (0.035 €/kWh) and natural gas (0.048 €/kWh), as reported in the earlier sections of the document. This adjustment ensures that the simulation captures the economic advantage of biomass-based heat production while maintaining consistency with the tool's internal pricing logic.

PLANHEAT ID KPI	KPI COMPLETE NAME	UNIT OF MEASURE	VALUE
EN_1	Primary energy consumption	MWh/year	41,871.87
	Specific primary energy consumption	MWh/m ² year	0.16
EN_2	Final energy consumption	MWh/year	27940.05
	Specific final energy consumption	MWh/m ² year	0.11
EN_3	Useful energy demand	MWh/year	23,497.4
	Specific useful energy demand	MWh/m ² year	0.09
EN_4	Primary energy consumption from RES	MWh/year	17,988.75
	RES share	%	42.96





EN_6	Primary energy consumption from Conventional Fuels	MWh/year	23,883.12
	Conventional Fuels share %	%	57.04
EN_9	Cooling share	%	0
EN_11	FEC Solar thermal	MWh/year	0
ENV_1	CO ₂ emissions	tCO ₂ /year	1,444.5
	Specific CO ₂ emissions	tCO ₂ / kWh (EN1) year	0.035
ECO_2.1	OPEX	M€/ year	0.972
	OPEX (+ Lighting and Equipment)	M€/ year	2.36

Table 11 KPIs Uponor and Biomass only DHN Solution Scenario

The biomass-only DHN scenario presented in Table 11 shows a compelling pathway toward decarbonizing the Riga Central Market district. By replacing natural gas entirely with biomass and integrating the UPONOR low-temperature heating system, the simulation achieves a significant increase in renewable energy share (42.96%) and a notable reduction in CO₂ emissions. The improved system efficiency, combined with the lower carbon intensity of biomass, contributes to a more sustainable energy profile.

Operational expenditures are also reduced, with total OPEX (including lighting and equipment) decreasing to 2.36 million €/year. However, the scenario highlights a critical limitation: the biomass availability within a 20 km radius of the district is insufficient to support full DHN supply, requiring imports from other regions. Additionally, increased biomass usage may lead to higher NO_x emissions, necessitating further technological investments.

It is important to note that the primary energy consumption in this scenario decreases only slightly compared to the UPONOR-only configuration. This limited improvement is mainly due to the small difference in the PEF between natural gas (1.1) and biomass (1.0). As a result, while the switch to biomass improves the renewable share and reduces emissions, its impact on primary energy KPIs remains modest.

Overall, the biomass-only DHN scenario demonstrates strong environmental and economic potential, provided that resource planning and emission mitigation strategies are carefully addressed.

6.2.3. SOLAR-THERMAL COLLECTORS

This scenario evaluates the integration of solar thermal collectors as a complementary renewable energy source within the Riga Central Market district. The simulation assumes the continued use of the UPONOR low-temperature heating system and explores the contribution of rooftop solar thermal installations to the district's energy mix. Given the limited rooftop area and modest solar yield estimated by the PLANHEAT tool, the role of solar thermal remains secondary. Biomass continues to serve as the primary renewable energy source, forming the backbone of the district heating network (DHN), with solar thermal providing only a minor share. Nevertheless, it may be of interest for the Riga Municipality to assess the potential of installing solar thermal panels in decommissioned or underutilized urban areas to enhance future renewable integration.





PLANHEAT ID KPI	KPI COMPLETE NAME	UNIT OF MEASURE	VALUE
EN_1	Primary energy consumption	MWh/year	41,863.9
	Specific primary energy consumption	MWh/m ² year	0.16
EN_2	Final energy consumption	MWh/year	27,931.5
	Specific final energy consumption	MWh/m ² year	0.11
EN_3	Useful energy demand	MWh/year	23,497.4
	Specific useful energy demand	MWh/m ² year	0.09
EN_4	Primary energy consumption from RES	MWh/year	10,458.4
	RES share	%	25.0
EN_6	Primary energy consumption from Conventional Fuels	MWh/year	41,405.4
	Conventional Fuels share	%	75.0
EN_9	Cooling share	%	0
EN_11	FEC Solar thermal	MWh/year	5.76
ENV_1	CO ₂ emissions	tCO ₂ /year	1,444.3
	Specific CO ₂ emissions	tCO ₂ / kWh (EN1) year	34.5
ECO_2.1	OPEX	M€/ year	0.967
	OPEX (+ Lighting and Equipment)	M€/ year	2.36

Table 12 KPIs Uponsor and Solar Thermal Solution Scenario

Although the simulation results present in Table 12 indicate that rooftop solar thermal collectors contribute only marginally to the district's energy supply, providing just 5.76 MWh annually, the scenario underscores the importance of diversifying renewable energy sources. The modest increase in renewable energy share and slight reduction in CO₂ emissions demonstrate that solar thermal can play a supporting role in broader decarbonization strategies. Moreover, the findings suggest that Riga Municipality could benefit from further investigating the deployment of solar thermal systems in non-rooftop areas, such as brownfields or decommissioned urban plots. This would enable a more substantial integration of solar energy and reinforce the district's transition toward a resilient and low-carbon future.





6.3. SHORT AND LONG-TERM DECARBONIZING STRATEGIES

6.3.1. SCENARIO A - BIOMASS-ONLY DHN

When it comes to converting into 100% biomass-based system. This change would eliminate dependence on natural gas entirely, representing a significant step toward carbon neutrality. It assumes the availability of sufficient sustainable biomass resources and addresses emissions by replacing fossil fuels with a renewable alternative. These key measures include short term planning such as:

- **Boiler Retrofit and Commissioning:** Existing gas-fired boilers will be decommissioned and replaced with modern grate or circulating fluidized-bed biomass boilers, leveraging proven technologies with > 90 % availability in European DH applications. Detailed design and procurement activities are expected to span 3-5 months, followed by a 3-12 month construction phase for integration of fuel-handling systems and emissions controls.

Supply-Chain Mobilization: To ensure continuous fuel supply, contracts will be established with local forestry operators to secure up to 4.5 Mt DM of low-restriction harvest residues annually, equivalent to ~ 23.9 TWh, without increasing harvest intensity. Supply agreements will include clauses mandating optimal drying and transport practices to maintain a lifecycle emission factor below 0.03 kg CO₂e/kWh.

- **Emission Control Upgrades:** Baghouse or electrostatic precipitator filters will be installed concurrently with boiler retrofits to guarantee compliance with PM_{2.5} emission limits of < 10 mg/Nm³. This measure not only addresses public air-quality concerns but also preempts potential regulatory barriers related to local odor and dust.
- **Financial Structuring:** Capital expenditure for small-scale biomass installations (400-750 €/kW boiler capacity) plus fuel-handling add-ons (≈ 350 €/kW) will be financed through a combination of municipal green bonds and leveraged feed-in tariffs under the TRACE BP scheme. Administrative budgets will include allowances for RED II sustainability audit fees of €5-10/MWh.
- **Workforce Readiness:** Rīgas Siltums' existing solid-fuel technicians will undergo targeted upskilling programs, partnering with European combustion institutes, to bridge the certification gap in CFB and biomass combustion operations.

By the end of the first 24 months, the DHN is expected to achieve full biomass firing at design capacity, translating into an immediate > 88 % reduction in combustion emissions (from 0.244 kg CO₂e/kWh to 0.027 kg CO₂e/kWh) and the elimination of all natural-gas usage in heat generation. Over the longer horizon (5-10 years), the DHN's strategy to shift from fuel substitution to holistic system optimization and deep decarbonization:

1. **Diversification of Renewable Feedstocks:** While forest residues will remain the backbone of fuel supply, the DHN will progressively integrate alternative biomass sources, such as agricultural residues and certified energy crops, to mitigate competition with pulp and pellet industries and to stabilize resource availability at > 90 % of annual demand. Continuous lifecycle assessments will be conducted to ensure average emissions remain below 0.05 kg CO₂e/kWh.
2. **Hybridization with Low-Carbon Heat Pumps:** In zones with lower density or lower temperature demand (e.g., newly developed residential areas), ground-source or waste-heat recovery heat pumps will be piloted. These units are anticipated to operate with seasonal COPs (coefficient of performance) of 3-4, enabling an additional 20-30 % reduction in primary energy use and associated emissions when coupled with district biomass boilers.
3. **Digitalization and Demand-Side Management:** Advanced real-time monitoring and control systems will be deployed across the network to optimize load dispatch, reduce distribution losses, and implement demand-response schemes. Predictive analytics will enable up to 10 % peak shaving of heating loads, deferring investments in peak boilers or network reinforcement.





4. **Integration of Carbon Capture Readiness:** The biomass boilers will be designed with flue-gas ductwork and space allowances to accommodate future small-scale carbon capture modules (e.g., post-combustion amine scrubbers). Feasibility studies will be completed by Year 5, evaluating the technical and economic potential to capture up to 90 % of biogenic CO₂, thereby converting the DHN into a net-negative emitter.
5. **Community Engagement and Policy Alignment:** Continuous public outreach programs will educate residents on the health benefits of centralized biomass DH versus individual wood stoves, fostering acceptance and buy-in. Collaboration with national authorities will aim to secure favourable revisions in RED III policies, reducing auditing overheads and extending investment incentives for carbon capture retrofits.

By the close of the decade, these measures are projected to drive the DHN toward full carbon neutrality, and even net-negative operation, while maintaining high reliability (> 95 %) and competitive heat tariffs.

6.3.2. SCENARIO B - SOLAR THERMAL COLLECTORS

When it comes to scenario B, In the short term, Riga's DHN will integrate solar thermal collectors and medium-term thermal storage to displace a portion of its natural-gas use, particularly during spring and autumn shoulder seasons and peak sun hours, while retaining gas boilers as backup. Key actions include:

- **Collector Field Deployment:** Install flat-plate or evacuated-tube solar collectors on available rooftop and ground-mounted sites, targeting an initial solar fraction of 10-15 % of annual heat demand. A phased rollout of 5 MW_{th} capacity is planned over 18 months, leveraging proven SDH designs with > 20 years of operational data.
- **Thermal Storage Integration:** Construct insulated buffer tanks (totalling approximately 2 GWh storage capacity) adjacent to major pumping stations. These tanks will capture midday solar heat for evening and early-morning use, reducing instantaneous peak boiler loads.
- **Control System Upgrades:** Extend the existing DHN automation platform to incorporate solar feed-in logic, dynamically prioritizing stored solar heat when temperatures exceed 40 °C. Operator training programs will be launched to familiarize staff with new dispatch algorithms and safe operation of stratified storage systems.
- **Financing and Incentives:** Secure up to 50 % of solar and storage CapEx (1 440-2 160 €/kW_{th} for collectors plus 200 €/kWh for tanks) from EU Cohesion Fund grants and national energy-efficiency programmes. Project budgets will include buffer for permitting delays under RED II Art. 16c, estimated at 3-4 months per installation.
- **Public Outreach:** Host demonstration events at collector sites to illustrate the visual and environmental benefits of solar integration, addressing concerns over urban landscape impacts and fostering local acceptance.

By the end of Year 2, these measures are expected to achieve a 10-15 % reduction in gas consumption during sunny months, decrease daily peak boiler firing by up to 20 %, and validate the technical readiness of large-scale solar thermal in Riga's climate. Over a 5-10 year horizon, the focus will shift toward maximizing solar yield, enhancing seasonal storage, and integrating complementary low-carbon technologies to deepen decarbonization:

1. **Expansion of Solar Capacity:** Gradually increase collector capacity to cover 25-30 % of annual heating load by Year 10, exploiting brownfield and canal-side land parcels. Continuous monitoring will refine site selection to mitigate winter irradiance limitations and optimize orientation.
2. **Seasonal Thermal Storage Pilots:** Develop underground or pit-storage systems capable of storing multi-GWh quantities of heat through summer for use in winter. Pilot designs will test borehole and lined gravel-pit concepts, aiming for round-trip efficiencies > 80 %.
3. **Hybridization with Heat Pumps:** In low-density zones, install electrically driven heat pumps, powered increasingly by PV, to supply low-temperature networks alongside solar. This hybrid approach is projected to further reduce gas use by 15-20 % and improve overall system COP.





4. **Advanced Energy Management:** Deploy machine-learning-based forecasting tools that predict solar yield and heat demand on an hourly basis, enabling pre-emptive charging of seasonal stores and optimized gas boiler scheduling to minimize fuel use and peak emissions.
5. **Policy and Market Evolution:** Advocate for the extension of 15-year feed-in incentives (akin to SDE++) to solar-thermal heat, and streamline permitting by pre-approving collector configurations under updated RED III guidelines. Continued engagement with city planners will ensure land-use plans accommodate expanding solar fields.
6. **Capacity Building:** Establish a Baltic Centre of Excellence for solar-thermal and storage engineering in Riga, offering certification courses and supporting local firms to reduce reliance on foreign specialists for large-scale tank design and integration.

By the end of the decade, these long-term measures are projected to raise the solar share of the DHN's heat supply to 30-35 %, reduce annual gas consumption by over 40 %, and position Riga as a Northern-European leader in integrated solar thermal district heating.

6.3.3. SCENARIO C - MODULAR HEAT PUMPS

In the immediate 1-2 year horizon, the DHN will deploy modular heat-pump units to electrify a portion of heat production, prioritizing low-temperature return loops and district extensions with high renewable-electricity penetration. The main actions are:

- **Modular Heat-Pump Rollout:** Install prefabricated air-source and water-source heat-pump skids totalling 10 MW_{th} capacity at two strategic pumping stations. These units, with COPs of 3-4 under nominal conditions, will be tied into existing low-temperature circuits, displacing gas boiler firing during mild weather periods.
- **Grid Connection and Load Management:** Coordinate with the local Distribution System Operator to secure grid connections for the new loads, phasing capacity additions to avoid distribution bottlenecks. Dynamic tariff negotiations will mitigate peak-demand charges and explore ESCO performance-contract models to defer up-front CapEx.
- **Renewable Electricity Sourcing:** Negotiate power-purchase agreements for 100 % renewable electricity to ensure that electrified heat delivers maximal CO₂ savings (up to 80 % relative to gas boilers).
- **Backup Integration and Controls:** Retain existing gas boilers as automated backup. The network SCADA will be updated with heat-pump dispatch logic, switching seamlessly between electric and gas heat based on ambient conditions and real-time electricity carbon intensity signals.
- **Workforce Preparation:** Launch a targeted training program in partnership with Skills4DHC to certify DHN operators and local HVAC technicians in heat-pump integration and cold-climate performance optimization.

By the end of Year 2, partial electrification is expected to supply 15-20 % of annual heat demand via heat pumps, reducing gas consumption by an equivalent amount and cutting district GHG emissions by up to 30 %, depending on real-time grid carbon intensity. Over a 5-10 year timeframe, the DHN will scale and optimize electrification while preparing for deeper grid and system synergies:

1. **Capacity Expansion:** Incrementally increase heat-pump capacity to cover 40-50 % of annual heat output, adding ground-source and waste-heat recovery units where grid constraints or noise concerns limit air-source deployment.
2. **Grid Reinforcement & Flexibility:** Coordinate €800 M worth of regional grid upgrades to accommodate peak electric-heating loads. Implement smart charging and demand-response schemes to flatten daily peaks and leverage variable-tariff windows.
3. **Hybrid Operation with Renewables:** Integrate on-site PV and wind installations at pumping stations to directly power heat pumps during daylight hours, reducing grid dependency and improving overall system COP.
4. **Advanced Control & Forecasting:** Deploy machine-learning algorithms that predict cold snaps and electricity-price fluctuations, optimizing heat-pump run schedules and minimizing backup gas use.
5. **Policy Engagement:** Advocate for finalization of EU Taxonomy technical-screening criteria to cement refrigerant GWP limits and efficiency standards, reducing regulatory uncertainty.





Secure Electrification Action Plan funding to co-finance future heat-pump installations under favourable terms.

6. **Full Workforce Certification:** Partner with regional technical institutes to establish a DHN-specific heat-pump curriculum, ensuring a pipeline of qualified engineers and installers for large-scale electrification projects.

By Year 10, these measures will position Riga's DHN to meet more than half of its heat demand electrically, achieving up to 70 % CO₂ reductions compared to baseline gas operation, and laying the groundwork for eventual synergy with long-duration storage or seasonal thermal networks.





7. CONCLUSION

The simulation results presented in Chapter 6.2 of this deliverable demonstrate the effectiveness and flexibility of the enhanced PLANHEAT tool in supporting climate-proof urban energy planning for the Riga Central Market district. The tool's upgraded functionalities, particularly the integration of historical heritage building profiles and electricity consumption modelling, enabled a robust evaluation of multiple future energy scenarios.

Three strategic configurations were analysed:

- **Scenario: UPONOR Low-Temperature Heating System**
This scenario yielded a modest reduction in primary energy consumption (-10.8%) and CO₂ emissions (-3.9%) compared to the baseline. The improvement is attributed to the increased efficiency of the heating distribution system, although the renewable energy share slightly decreased due to the unchanged energy source mix.
- **Scenario: Biomass-Only District Heating Network**
By replacing natural gas with biomass across the DHN and maintaining the UPONOR system, this scenario achieved a significant increase in renewable energy share (42.96%) and a substantial reduction in CO₂ emissions (-57.5%). Operational expenditures were also reduced by 23.4%, confirming the economic viability of biomass-based heat supply. However, the limited availability of biomass within a 20 km radius poses a constraint for full-scale implementation.
- **Scenario: Solar Thermal Collectors Integration**
The addition of rooftop solar thermal collectors contributed only marginally to the district's energy supply (5.76 MWh/year), resulting in a negligible increase in renewable share (+0.5%) and minimal impact on CO₂ emissions. Nonetheless, this scenario highlights the potential of solar thermal as a complementary resource, especially if deployed in underutilized urban areas.

Across all scenarios, the PLANHEAT tool proved capable of simulating complex urban energy systems and quantifying the impact of technological upgrades and renewable integration. The results underscore the importance of combining efficient distribution technologies with renewable energy sources to achieve meaningful decarbonization.

In conclusion, the Riga Central Market district exhibits strong potential for energy transition through targeted interventions. The biomass-only DHN scenario emerges as the most impactful in terms of environmental and economic performance, while the UPONOR system offers a scalable and heritage-compatible solution. Solar thermal integration, although limited in current scope, may serve as a strategic enhancement in future urban planning.

These findings provide actionable insights for municipal stakeholders and urban planners, supporting the development of resilient, low-carbon energy strategies aligned with EU climate objectives.





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