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multiclimact

D8.3 – DEVELOPING LCC, LCA AND SLCA METHODS FOR SUPPORTING THE PLANNING AND DESIGN OF INTERVENTIONS ON THE BUILT ENVIRONMENT– APPLICATION TO A REAL DEMO

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MULTICLIMACT
D8.3 - DEVELOPING LCC, LCA AND SLCA METHODS FOR SUPPORTING THE PLANNING AND DESIGN OF INTERVENTIONS ON THE BUILT ENVIRONMENT- APPLICATION TO A REAL DEMO

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Abbreviations and Acronyms

ACRONYM	DESCRIPTION
ADP	Abiotic Depletion Potential
AP	Acidification Potential
CINEA	European Climate, Infrastructure and Environment Executive Agency
eLCA	Environmental Life Cycle Assessment
EN	European Norm
EPD	Environmental Product Declaration
GWP	Global Warming Potential
GHGs	Greenhouse Gases
HVAC	Heating, Ventilation and Air Conditioning
JRC	Joint Research Centre
ILCD	International Life Cycle Data System
ISO	International Organization for Standardization
KTH	KUNGLIGA TEKNISKA HOEGSKOLAN
LC	Life Cycle
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCT	Life Cycle Thinking
LULUC	Land Use and Land-Use Change
m^2	Square meter
m^3	Cubic meter
MJ	Megajoule
MULTICLIMACT	MULTI-faceted CLIMate adaptation ACTions to improve resilience, preparedness and responsiveness of the built environment against multiple hazards at multiple scales
ODP	Ozone Layer Depletion Potential
PSILCA	Product Social Impact Life Cycle Assessment (Database)
PV	Photovoltaic

ACRONYM	DESCRIPTION
REA	RIGA MUNICIPAL AGENCY "RIGA ENERGY AGENCY"
RES	Renewable Energy Source
sLCA	Social Life Cycle Assessment
RINA-C	RINA Consulting
UKA	Universitaetsklinikum Aachen
UNEP/SETAC	United Nations Environment Programme / Society of Environmental Toxicology and Chemistry
Uponor	UPONOR OYJ
WP	Work Package

Executive Summary

This report is a deliverable of the project **"MULTICLIMACT - MULTI-faceted CLIMate adaptation ACTions to improve resilience, preparedness and responsiveness of the built environment against multiple hazards at multiple scales"**, funded by the European Commission through the European Climate, Infrastructure and Environment Executive Agency (CINEA). MULTICLIMACT pursues scientific, technological, and non-technological objectives in 17 Work Packages (WPs) organized in three interlinked phases: 1) Plan and Design; 2) Develop and Test; 3) Deploy and Revise.

The planning and design carried out in the first phase are put in practice in Phase 2, where MULTICLIMACT CREMA tool and the design, materials and solutions toolkit are developed for their application in a real context. WP8 led by "Universitaetsklinikum Aachen" (UKA) contributes to this aim by developing methods supporting natural hazards mitigation and sustainability at multiple scales. Such methods comprise, among other things, also life cycle assessment methodology considering environmental and social aspects of the designed intervention on the built environment.

This deliverable (D8.3) represents cradle-to-gate life cycle impact assessment methods developed to assess the environmental and social impacts associated to the implementation of the innovative solutions in the historical building in Latvian demo site developed by RINA Consulting S.p.A (RINA-C) in collaboration with the project partners RIGA MUNICIPAL AGENCY "RIGA ENERGY AGENCY" (REA) and UPONOR OYJ (Uponor).

This report is built over the best practices and approaches introduced in the MULTICLIMACT deliverable D2.3 and provides a detailed description of the main phases of the life cycle approach tailored for the project use case defining key parameters and data requirements. The assessment results will be presented with WP11 and WP15 deliverables as part of testing and demonstration of the developed methods and considering real demo site data collected as part of Task 11.4 and Task 15.4 activities.

D8.3 briefly introduces the key phases and requirements of the LCA methodology, including goal and scope definition, inventory analysis, impact assessment, and interpretation for eLCA and sLCA. It then focuses on the application of these methodologies to the specific solution to be implemented in the Latvian demo site. The deliverable presents key elements such as the definition of system boundaries, development of data collection checklists, identification of potential risks and assumptions, and selection of relevant environmental indicators, modelling software, and reference datasets will be established. In collaboration with WP11 and WP15 partners, data will be collected from the demo site and relevant partners. RINA-C will then conduct the LCA and sLCA modelling and present the results, including interpretation of findings as part of the overall testing activities.

1. INTRODUCTION

As stated in the Grant Agreement (GA), **MULTICLIMACT** aims to develop a mainstreamed framework and a tool for supporting public stakeholders and citizens to assess the resilience of the built environment and its people at multiple scales (buildings including cultural heritage, urban areas, infrastructures) against locally relevant natural and climatic hazards and supply-chains, as well as to support them to enhance their preparedness and responsiveness across their life cycle. The mainstreamed approach includes a resilience scorecard system and a toolkit of Design Practices, Materials, and Digital Solutions enabling public stakeholders and citizens in planning, designing, implementing and monitoring solutions to improve the built environment and human resilience and its protective role against climate and natural hazards.

Part of the activity of the second phase is dedicated to the develop and test of the MULTICLIMACT toolkit: **WP8 "Design practices and methods for supporting natural hazards mitigation and sustainability at multiple scales"** is addressed at the development of planning and design methods, particularly focusing on their demonstration in real contexts. Each design/planning method will be further developed in order to be then tested in a MULTICLIMACT demo site. In this framework, **Task 8.3 "LCA, sLCA and other life-cycle methods supporting the planning and design of interventions on the built environment at multiple scales - development for the application to a real demo case",** is one of the six tasks of WP8 included in the 2nd phase of the project "*Develop*" relates to development of the life-cycle assessment and a social life-cycle assessment models to identify the main environmental and social impacts associated to the implementation of the innovative solutions in the historical building subject of Latvian demo and comparing them with the environmental and social benefits achieved in order to foster the replication at other scales. The analysis will be carried out via simplified life cycle approaches already tested in other EU co-funded R&D projects and will follow a "cradle-to-gate" approach.

This deliverable represents the main output of task 8.3 led by RINA Consulting S.p.A (RINA-C) in collaboration with the project partners RIGA MUNICIPAL AGENCY "RIGA ENERGY AGENCY" (REA) and UPONOR OYJ (Uponor).

The deliverable is structured as follows:

Chapter 1: serves as the document's introduction;

Chapter 2: presents the deliverable and task 8.3 objective and expected impact;

Chapter 3: provides the overall approach to meet the task objectives;

Chapter 4: defines the main terms related to the environmental and social life cycle assessment;

Chapter 5: presents the methodology to develop an environmental and social life cycle analysis;

Chapter 6: details the methodology adopt to define the environmental and social life cycle model for the implementation of the innovative solutions in the historical building subject of Latvian demo;

Chapter 7: defines the approach to assess the environmental and social benefits of the intervention on the Latvian demo;

Chapter 8: presents the outputs to other work packages;

Chapter 9: serves as a the document's conclusion.

1.1. PURPOSE AND TARGET GROUP

This deliverable aims to present the methodology and the model to conduct the Environmental Life Cycle Assessment (eLCA and Social Life Cycle Assessment (sLCA) of the implementation of the defined RES-based HVAC solution developed by UPONOR (developed in T3.3 and T9.3) in Latvian demo (Riga

Central market). It provides the model including approach, boundaries, required data and the indicators for assessing the environmental and social impacts from raw material extraction to implementation of the solution based on the identified standards and guidelines and referring to studies from the literature.

This deliverable will outline how the environmental and social life cycle assessment methodologies identified in Deliverable D2.3 "LCC, LCA, sLCA for planning and designing of resilience enabling interventions on the built environment at multiple scales" can be applied to a real case demo site, detailing the requirements and steps involved at each phase of the assessment. It will serve as the theoretical model to be tested in WP11, Task 11.4, where data will be collected from the implementation of the solution at the demo site. The model will then be executed, and the results will be analysed and presented.

The deliverable is intended for RIGA site representatives and the Project partners as well as for decision-makers and policy makers for informed urban planning and sustainability policies, planners, designers, architects and engineers to integrate sustainability assessments into the solutions designs and implementation. Also, for construction companies to consider the sustainability indicators during the identification of suppliers, used materials and equipment and to implement best practices in construction and renovation. Academic and research institutions, project involved partners and stakeholders.

1.2. CONTRIBUTIONS OF PARTNERS

The task was led by RINA with the contribution of REA and UPONOR in the definition of the boundaries of the analysis, data collection and analysis and the elaboration of specific section in the deliverable D8.3. The following table presents the main contributions from project partners in the development of this deliverable.

Table 1: Contributions of Partners

PARTNER SHORT NAME	CONTRIBUTIONS
REA	Specific contribution to sections 6.1
RINA-C	Overall content of deliverable, Specific contribution to all sections
UPONOR	Specific contribution to section 6.1

2. OBJECTIVES AND EXPECTED IMPACT

WP8 is dedicated to the development of design practices and methods supporting natural hazards mitigation and sustainability at multiple scales that will be next then tested and monitored in a MULTICLIMACT demo site within WP11 and WP15 activities. WP8 is dedicated to consolidating the work carried out in WP2 to meet the Scientific and Technological Objectives (STO) of the Project namely STO2 - Developing the MULTICLIMACT toolkit: DESIGN practices and methods - Creating a set of best practices and methods to Plan and Design interventions on the built environment supporting and enhancing its resilience to natural hazards, and to reach the Milestone 5 - Successful design and development of the MULTICLIMACT toolkit (Figure 1: *Task Overview and relation to other tasks*).

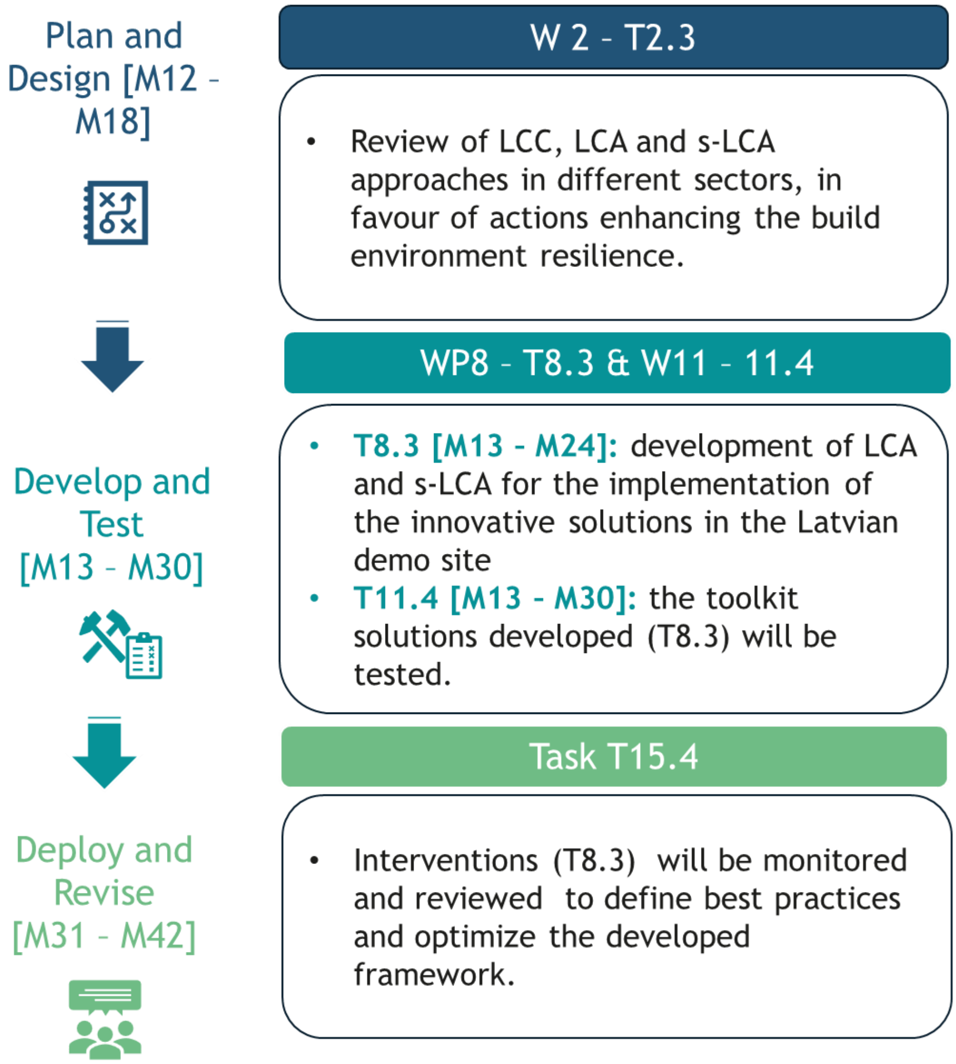

Figure 1: Task Overview and relation to other tasks

Life cycle thinking techniques and tools, such as Environmental Life Cycle Assessment, Life Cycle Costing, and Social Life Cycle Assessment has been extensively applied in the building sector for assessing the environmental performance and impact of construction materials and products throughout the entire life cycle of a construction, is a widespread instrument to support decision-making, and it can be applied also as a support to cultural heritage management, as well as urban management in general.

The methodologies and best practices outlined in Deliverable D8.3 set out the foundation for developing the Environmental Life Cycle Assessment and Social Life Cycle Assessment models related to the interventions planned for the Latvian demo site, with a particular focus on the RES-HVAC system designed by Uponor under WP11 and WP15.

At this stage, key elements such as the definition of system boundaries, development of data collection checklists, identification of potential risks and assumptions, and selection of relevant environmental indicators, modelling software, and reference datasets will be established.

In collaboration with WP11 partners, data will be collected from the demo site and relevant partners. RINA-C will then conduct the LCA and sLCA modelling and present the results, including interpretation of findings as part of the overall testing activities.

The general objective of T8.3 is to support and orientate decision-makers to the planning and designing interventions on the built environment that can take to improve the environmental and social performance aspects of the built environment. Additionally, this deliverable contributes to achieving project STO2 that consists of developing the MULTICLIMACT toolkit design practices and methods and creating a set of best practices and methods to plan and design interventions on the built environment supporting and enhancing its resilience to natural hazards. The expected result during the project is to go from the current TRL 5 of the life cycle methods supporting the planning and design of the interventions on the built environment to TRL 7.

3. OVERALL APPROACH

Within T8.3 a life-cycle assessment and a social life-cycle assessment will be carried out with the aim of identifying the main environmental and social impacts associated to the implementation of the innovative solutions in the historical building subject of Latvian demo and comparing them with the environmental and social benefits achieved to foster the replication at other scales.

The analysis will be carried out via simplified life cycle approaches already tested in other EU co-funded R&D projects and will follow a "cradle-to-gate" approach (from raw materials extraction and production, pilot realization and process operation, up to the production of the final product). Most of the input data needed for the analysis will be gathered internally to the consortium, based on the parameters monitored at the demo site and validated by specific experts; background data will be taken from international LCI databases and relevant scientific literature, which will also be used as a source to fill potential other data gaps for the execution of the LCA. The" cradle-to-gate" approach consists of measuring the environmental, social impacts and costs of the solution or product from resource extraction (*cradle*) to the factory gate (i.e., before it is transported to the consumer).

Task 8.3 can be divided to two main sub-tasks:

1. Development of the environmental LCA and social LCA models
2. Definition of the approach to analyse the environmental and social benefits achieved.

For the development of the environmental life cycle assessment model, RINA will start with an initial data collection and validation phase through a series of meetings and exchange of reference documents aimed at gathering an overview on the solution to be implemented (the RES-HVAC system), including the expected output, manufacturing supply chain and any available environmental studies and the solution installation timeline and activities. This phase will enable the definition of the goal and scope of the LCA and development of the data collection checklist. Then, RINA-C will carry out an initial round of data collection and validation based on preliminary design of the solution and the feedback from Task 11.4 results and identify any risks such as data availability and quality and possible alternatives options. The initial collected data will be analysed, and further rounds of data gathering will be conducted within WP11 to ensure the completeness, accuracy, and reliability of the LCA results. Additionally, RINA will define the environmental assessment indicators, as well as appropriate modelling tools and reference databases, will be identified and selected based on the specificities of the intervention. The data final impact assessment results, including interpretation and key findings, will be presented as part of Task 11.4 deliverable. In parallel, the social LCA will be developed by applying the Product Social Impact Life Cycle Assessment (PSILCA) database within the OpenLCA software an open-source software for Life Cycle Assessment, following the United Nations Environment Programme / Society of Environmental Toxicology and Chemistry (UNEP/SETAC) methodological framework. The assessment will focus on identifying potential social risks related to labour rights, occupational safety, human rights, and community well-being across the upstream supply chain of the RES-HVAC system. Sector- and country-specific data will be used to model key processes involved in component manufacturing, transport, and installation. The functional unit and scope of the social LCA will be harmonised with the environmental LCA to ensure consistency and comparability. The assessment will consider both foreground and background processes, and the results will be expressed in terms of risk hours across relevant impact categories. Particular attention will be given to differences between the baseline and intervention scenarios, aiming to identify the net social benefits introduced by the MULTICLIMACT solution. Interpretation of results will account for data quality and uncertainty, and qualitative insights will complement the quantitative outputs where needed.

Building on the information and inputs gathered during the definition of the LCA models and considering the data availability and system complexity, RINA will define the approach to analyse the achieved benefits focusing mainly of the operational phase. The analysis will refer to quantitative and qualitative methods tacking into accounts the progress of activities with Task 11.4 and Task 15.4 and the available data.

4. TERMS AND DEFINITIONS

These terms and definitions are derived from ISO 14040:2006 and included in this deliverable for user convenience.

Life cycle

The consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.

Life cycle assessment (LCA)

The compilation and evaluation of the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle.

Life cycle inventory analysis (LCI)

The phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.

Life cycle impact assessment (LCIA)

The phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product.

Life cycle interpretation

The phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations.

Comparative assertion

An environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function.

Transparency

The open, comprehensive, and understandable presentation of information.

Environmental aspect

An element of an organization's activities, products, or services that can interact with the environment.

Product

Any goods or service, including services, software, hardware, and processed materials. Services can include activities performed on tangible or intangible products, delivery of intangible products, or creation of ambience. Software and hardware are generally tangible or intangible, while processed materials are tangible.

Co-product

Any of two or more products coming from the same unit process or product system.

Process

A set of interrelated or interacting activities that transforms inputs into outputs.

Elementary flow

Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation.

Energy flow

Input to or output from a unit process or product system, quantified in energy units. Energy input and output are specific terms for energy flows entering or leaving the system.

Feedstock energy

Heat of combustion of a raw material input that is not used as an energy source to a product system, expressed in terms of higher heating value or lower heating value. Care is necessary to ensure that the energy content of raw materials is not counted twice.

Raw material

Primary or secondary material used to produce a product, including recycled material.

Ancillary input

Material input used by the unit process producing the product, but not constituting part of the product.

Allocation

Partitioning the input or output flows of a process or product system between the product system under study and one or more other product systems.

Cut-off criteria

Specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product systems to be excluded from a study.

Data quality

Characteristics of data that relate to their ability to satisfy stated requirements.

Functional unit

Quantified performance of a product system used as a reference unit.

Input

Product, material, or energy flow that enters a unit process.

Intermediate flow

Product, material, or energy flow occurring between unit processes of the product system being studied.

Intermediate product

Output from a unit process that is input to other unit processes requiring further transformation within the system.

Life cycle inventory analysis result (LCI result)

Outcome of a life cycle inventory analysis that catalogs the flows crossing the system boundary and provides the starting point for life cycle impact assessment.

Output

Product, material, or energy flow that leaves a unit process, including raw materials, intermediate products, co-products, and releases.

Process energy

Energy input required for operating the process or equipment within a unit process, excluding energy inputs for production and delivery of the energy itself.

Product flow

Products entering from or leaving to another product system.

Product system

Collection of unit processes with elementary and product flows, performing one or more defined functions, and modelling the life cycle of a product.

Reference flow

Measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit.

Releases

Emissions to air and discharges to water and soil.

Sensitivity analysis

Systematic procedures for estimating the effects of choices regarding methods and data on the outcome of a study.

System boundary

Set of criteria specifying which unit processes are part of a product system. This term is not used in this International Standard in relation to LCIA.

Uncertainty analysis

Systematic procedure to quantify the uncertainty introduced in the results of a life cycle inventory analysis due to the cumulative effects of model imprecision, input uncertainty, and data variability. Ranges or probability distributions are used to determine uncertainty in the results.

Unit process

Smallest element considered in the life cycle inventory analysis for which input and output data are quantified.

Waste

Substances or objects which the holder intends or is required to dispose of. This definition is adapted from the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (22 March 1989) but is not confined to hazardous waste.

Category endpoint

Attribute or aspect of the natural environment, human health, or resources, identifying an environmental issue giving cause for concern.

Characterization factor

Factor derived from a characterization model used to convert a life cycle inventory analysis result to the common unit of the category indicator. This allows for the calculation of the category indicator result.

Environmental mechanism

System of physical, chemical, and biological processes for a given impact category, linking life cycle inventory analysis results to category indicators and category endpoints.

Co-funded by the European Union

Impact category

Class representing environmental issues of concern to which life cycle inventory analysis results may be assigned.

Impact category indicator

Quantifiable representation of an impact category, referred to as "category indicator" for readability.

Completeness check

Process of verifying whether information from the phases of a life cycle assessment is sufficient for reaching conclusions in accordance with the goal and scope definition.

Consistency check

Process of verifying that the assumptions, methods, and data are consistently applied throughout the study and are in accordance with the goal and scope definition before conclusions are reached.

Sensitivity check

Process of verifying that the information obtained from a sensitivity analysis is relevant for reaching conclusions and making recommendations.

Evaluation

Element within the life cycle interpretation phase intended to establish confidence in the results of the life cycle assessment. This includes completeness check, sensitivity check, consistency check, and any other validation required by the goal and scope definition of the study.

Critical review

Process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment.

Interested party

Individual or group concerned with or affected by the environmental performance of a product system, or by the results of the life cycle assessment

Social life cycle assessment (sLCA)

The compilation and evaluation of the inputs, outputs, and potential social and socio-economic impacts of a product system throughout its life cycle.

Social impact

Any effect on working conditions, human rights, health and safety, or community well-being resulting from the activities within a product system.

Social risk

The potential for negative social outcomes associated with a process or sector, typically assessed based on regional and sectoral indicators.

Stakeholder

An individual or group that is affected by or can affect a decision, activity, or outcome of a product system, including workers, local communities, value chain actors, and society at large.

Subcategory indicator

A measurable or semi-quantitative metric used in sLCA to evaluate performance within a specific social theme, such as child labour or fair salary.

Reference unit (social LCA)

The quantified function of the product system used as a basis for calculating social impacts, typically aligned with the functional unit used in environmental LCA.

Social theme

A grouping of related social indicators representing a specific area of concern, such as labour rights, health and safety, or access to basic services.

Risk hour

The unit used in PSILCA to express social risk levels, representing the number of labour hours potentially exposed to a certain risk category.

PSILCA (Product Social Impact Life Cycle Assessment)

A database and methodology that enables the quantification of social impacts using generic sector and country-level risk data linked to input flows in LCA models.

OpenLCA

An open-source software used for life cycle assessment modelling, including both environmental and social LCA applications.

5. THE LIFE CYCLE ASSESSMENT METHODOLOGY

5.1. ENVIRONMENTAL LIFE CYCLE ASSESSMENT METHODOLOGY

Life Cycle Assessment (LCA) referred to as the Environmental Life Cycle Assessment (eLCA) is a structured, comprehensive and internationally standardized method used to quantify all relevant emissions and resources consumed and the related health impacts and resource depletion issues that are associated with the Product over its life cycle[1].

This section will present the LCA methodology and its phases.

5.1.1. REFERENCE STANDARDS

For the eLCA, the analysis will refer to following standards:

- The international standards that guide LCA assessment are primarily found within the ISO 14000 series, specifically ISO 14040:2021, which outlines the principles and framework for conducting LCA, and ISO 14044:2021, which specifies requirements and provides guidelines for the assessment process. These standards establish a comprehensive methodology for evaluating the environmental impacts of products and services throughout their entire life cycle
- "ILCD Handbook – General Guide for Life Cycle Assessment – Detailed Guidance," published by the Joint Research Centre (JRC) of the European Commission, serves as a crucial reference for LCA practices. This handbook provides detailed instructions on conducting LCA studies, ensuring consistency and quality in the assessment process.
- the JRC's "Recommendations for Life Cycle Impact Assessment in the European Context" is particularly relevant. This document offers guidance on selecting appropriate impact categories and methodologies for evaluating environmental impacts, ensuring that assessments align with European standards
- The Product Category Rules or PCRs provide the instructions for how the LCA should be conducted. PCRs define the rules, requirements, and guidelines for developing an Environmental Product Declaration (EPD) for a specific product category.

Together, these standards and guidelines form a robust framework that supports effective LCA practices, promoting transparency and reliability in environmental assessments across various sectors.

5.1.2. PHASE OF THE ANALYSIS

LCA is usually performed in four iterative stages: goal definition, inventory, impact assessment, and interpretation. The chart in Figure 2 presents the key steps of LCA, which will be explained with more details in the following paragraphs. An important aspect to be considered is the iterative aspect of the LCA. Initially, the scope settings are based on the goal and application of the study that identifies the requirements of the subsequent phases. During the LCI and LCIA phases based on the collected data, impact assessment results and interpretation, more information becomes available which necessitates to redefine or revise the scope of the study.

1 ILCD Handbook - General guide on LCA - Detailed guidance 2010

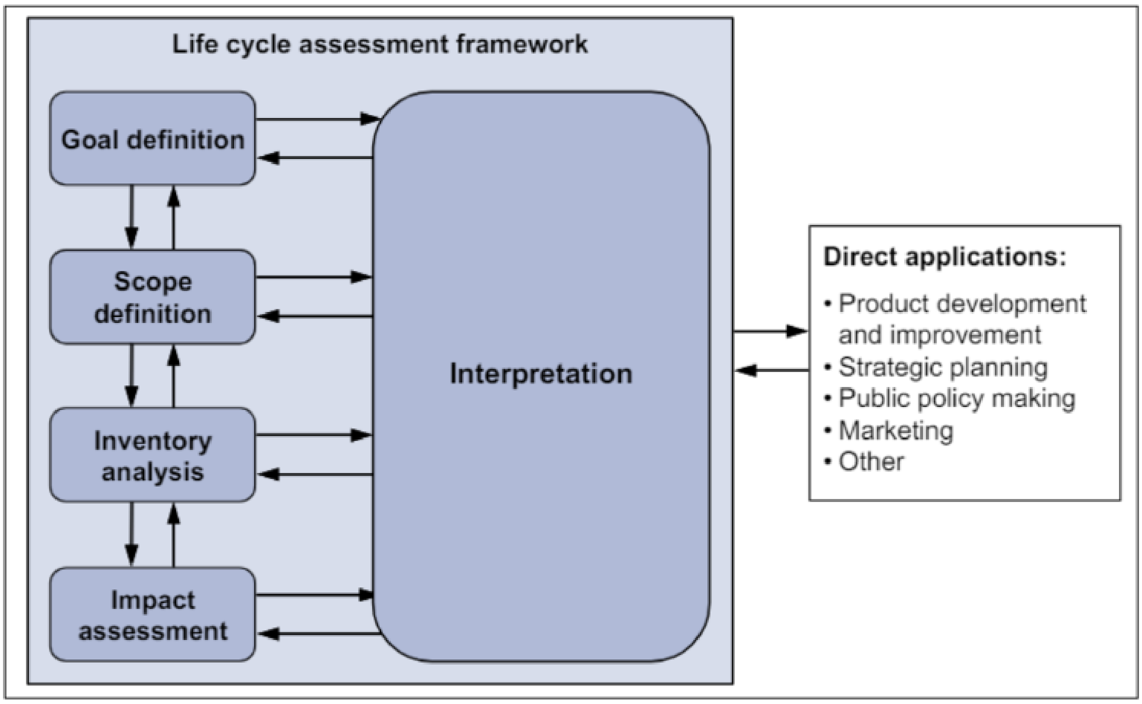

Figure 2: LCA Framework (ILCD Handbook - General guide on LCA - Detailed guidance)

5.1.2.1. Goal Definition:

The "goal definition" phase specifies the purpose of the LCA of the product, service, or process. In particular, the following aspects have to be described:

- **Intended application(s) of the study**, identifying the LCA applications; the most frequently used ones are: comparison of specific goods or services, benchmarking of specific products against the product group's average, development of the "Carbon footprint", "Primary energy consumption", development of a life cycle-based Type III environmental declaration for a specific good or service, etc.;
- **Method, assumption and impact limitations**, describing (if any) specific limitations of the usability of the results of the LCA, due to the applied methodology (e.g. a specific LCI can limit the possibility to draw general conclusions or to use the resulting LCI data in other studies), assumptions (e.g. assumptions on specific scenarios can limit the usability and transferability of the results) or impact-coverage (e.g. in the case of Carbon footprint calculations where exclusively climate change related greenhouse gas emissions are considered);
- **Reasons for carrying out the study, and decision-context**, defining drivers and motivations of the LCA and identifying the decision-context, classifying the situation among situation A ("Micro-level decision support", for product-related questions), B ("Meso/macro-level decision support, for strategies related to the raw materials, technology scenarios, policy options, etc.) or C ("Accounting" without decision support, C1 including interactions with other systems, C2 excluding interactions with other systems);
- **Target audience, type of audience,** specifying the audience to whom the results of the LCA are intended to be communicated and the type of audience (internal, restricted external, public, technical non-technical);
- **Comparisons intended to be disclosed to the public**, explicitly stating whether the LCA includes comparisons or comparative assertions and whether the comparisons are foreseen to

be disclosed to the public (i.e., an audience outside the commissioner and the involved experts);

- **Commissioner of the study and other influential actors**, identifying, if useful, the commissioner of the LCA and other influential actors.

5.1.2.2. Scope definition:

The "Scope definition" phase identifies and defines in detail the object of the LCA, in line with the goal definition. Several aspects have to be specified in this phase.

- The system or process analysed (with a detailed description of the analysed system and photos) and its function, functional unit and reference flow(s) have to be clarified in the LCA. The function(s) of the analysed system or process, defined as the quantified performance of a product system to be used as a reference unit, have to be defined, as well as the functional unit. The functional unit specifies the qualitative and quantitative aspects of the function(s) along the questions "what", "how much", "how well", and "for how long", permitting to perform valid comparisons. The reference flow is the measure of the outputs from processes in each product system required to fulfil the function expressed by the functional unit. It is the flow (or flows in case of multifunctional processes) to which all other input and output flows (i.e., all elementary flows[2] and non-reference product and waste flows) quantitatively relate;
- The Life Cycle Inventory (LCI) modelling framework and handling of multifunctional processes and products (if any) have to be described. The LCI modelling principles (attributional or consequential modelling) and method approaches (allocation or system expansion / substitution approaches) applied in the modelling of the system have to be indicated. The attributional (or "accounting", "retrospective", or "descriptive") LCI modelling principle depicts the potential environmental impacts that can be attributed to a system over its life cycle, i.e., upstream[3] along the supply chain and downstream following the system's use and end-of-life value chain. Attributional modelling makes use of historical, fact-based, measurable data of known (or at least know-able) uncertainty and includes all the processes that are identified to relevantly contribute to the system being studied.
- In attributional modelling, the system is modelled as it is or was (or is forecasted to be). The consequential life cycle inventory modelling principle (also called, "effect-oriented", "decision-based", or "market-based") identifies and models all processes in the background[4] system in consequence of decisions made in the foreground[5] system. The consequential life cycle model does not reflect the actual (or forecasted) specific or average supply-chain, but a hypothetic generic supply-chain is modelled that is prognosticated along market-mechanisms, and potentially including political interactions and consumer behaviour changes
- System boundaries, completeness requirements, and related cut-off rules must be clarified in an LCA study. The system boundaries define which parts of the life cycle, and which processes belong to the analysed system, i.e., are required for providing its function as defined by its functional unit. They hence separate the analysed system from the rest of the techno sphere. At the same time, the system boundaries also define the boundary between the analysed system and the ecosphere.

[2] Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation

[3] Upstream and downstream: processes included in the background system

[4] The background system includes all those processes, where generic data are used

[5] The foreground system includes all those processes, where specific data are used.

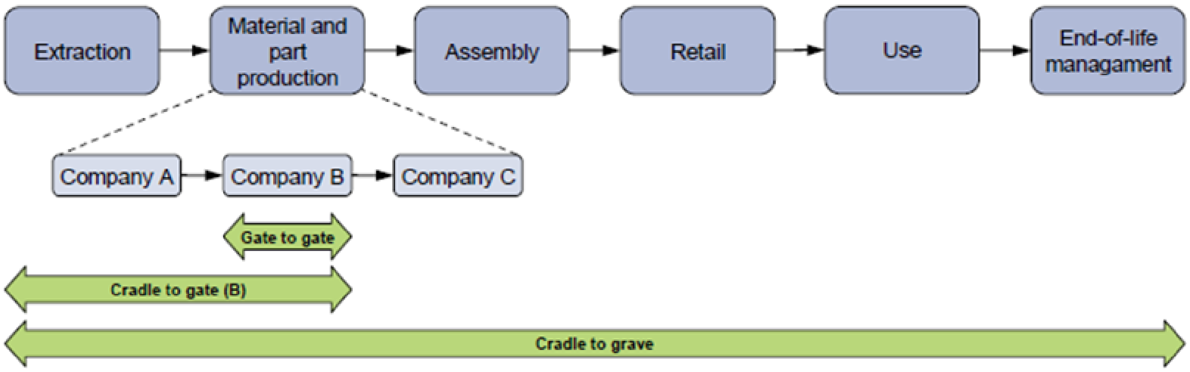

Figure 3: Schematic representation of a "cradle to grave", "cradle to gate" and "gate to gate" data sets as parts of the complete life cycle. (ILCD Handbook, General guide for LCA, Detailed Guidance.)

The analysed system may be divided into the foreground system of processes that are specific to the analysed system and the background system of processes that are not specific to the analysed system. The system is the exact sum of the background and the foreground systems.

The system boundaries define the life cycle approaches to be adopted. A life cycle of a product or system can be divided into different stages depending on the scope of the analysis (Figure 3). The cradle to grave scope of LCA considers the environmental impacts of a product from the extraction of raw materials (Cradle) to the disposal of the product at the end of its life (Grave). The Cradle to Gate LCA assesses a partial life cycle of a product from raw material extraction (Cradle) to the point where our product leaves our production facilities (Gate). To be noted the "Gate" depends on the analysed product or process. A Gate-to-Gate analysis focus on the use or operational stage of the product or analysed system.

Quantitatively irrelevant flows can be excluded, i.e., cut-off. "Cut-off" refers to the omission of not relevant life cycle stages, activity types (e.g., investment goods, storage, etc.), specific processes and products, and elementary flows from the system model. They are considered "not relevant" if their impacts on the global impact are estimated less than a precise percentage, e.g., 5%. This operation requires approximation since the total inventory is always unknown for all life cycle approaches. The cut-off criteria for initial inclusion of inputs and outputs and the assumptions on which the cut-off criteria are established shall be clearly described. Several cut-off criteria are used in LCA practice to decide which inputs are to be included in the assessment, such as mass, energy, and environmental significance;

- LCIA impact categories and selection of specific LCIA methods to be applied as well as if included normalization data and weighting set, must be described in the LCA study. The selection of impact categories[6], category indicators[7] and characterization models[8] used in the LCIA methodology shall be consistent with the goal of the study and shall be in line with ISO 14044:2021.

[6] The impact categories are classes representing environmental issues of concern to which life cycle inventory analysis results may be assigned.

[7] The impact category indicator is the quantifiable representation of an impact category.

[8] Characterization models reflect the environmental mechanism by describing the relationship between the LCI results, category indicators and, in some cases, category endpoint(s) (i.e., attribute or aspect of natural environment, human health, or resources, identifying an environmental issue giving cause for concern). The characterization model is used to derive the characterization factors (i.e., factors derived from a characterization model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator).

5.1.2.3. Life Cycle Inventory (LCI) analysis:

During the LCA Inventory Analysis phase, the data collection (specific and generic data collection) and modelling of the system (e.g., product) is performed through a dedicated software for the LCA, in line with the goal definition and meeting the requirements derived in the scope phase. The LCI results are the input to the subsequent LCIA phase.

Data are generally collected in several ways:

- Directly measured – this procedure mostly refers to data linked to use phases;
- Extracted from data sheets provided by suppliers – this procedure mostly refers to parts under purchase;
- Extracted from literature;
- Calculated based on specific formulas taken from literature – this procedure mostly refers to data conversion;
- Estimated, based on experience of technicians – this procedure is used when none of previous procedures are applicable and only applies to not relevant data.

The Inventory phase involves the collection of the required data for flows to and from processes:

- Elementary flows (such as resources and emissions but also other interventions with the ecosphere such as land use);
- Product flows (i.e., goods and services both as "product" of a process and as input/consumables) that link the analysed process with other processes;
- Waste flows (both wastewater and solid/liquid wastes) that need to be linked with waste management processes.

After the data collection, the data validation is performed to evaluate the technological, geographical, and time related representativeness of the data, the accuracy of data and the handling of the missing data.

5.1.2.4. Life Cycle Impact Assessment (LCIA):

Life Cycle Impact Assessment is the phase where the inputs and outputs of elementary flows that have been collected and reported in the inventory are translated into environmental results. It is important to note that LCA and the impact assessment analyses the potential environmental impacts that are caused by interventions that cross the border between techno sphere and ecosphere and act on the natural environment and humans, often only after fate and exposure steps.

Regarding the LCA, LCIA is composed of mandatory and optional steps:

- Classification step, i.e., the assignment of LCI results to the selected impact categories, including the assignment of LCI results that are exclusive to one impact category and the identification of LCI results that relate to more than one impact category, including the distinction between parallel mechanisms (e.g. $SO2$ is apportioned between the impact categories of human health and acidification), and the assignment to serial mechanisms (e.g. NO_x can be classified to contribute to both ground-level ozone formation and acidification);
- Characterization step, i.e., the calculation of category indicator results. The calculation of indicator results involves the conversion of LCI results to common units and the aggregation of the converted results within the same impact category. This conversion uses characterization factors. The outcome of the calculation is a numerical indicator result;
- Normalization step (optional), the LCIA results can be multiplied with normalization factors that represent the overall inventory of a reference (e.g., a whole country or an average citizen), obtaining dimensionless, normalized LCIA results;
- Weighting step (optional) step these normalized LCIA results can be multiplied by a set of weighting factors, that indicate the different relevance that the different impact categories (midpoint level related weighting) or areas-of-protection (endpoint level related weighting) may

have, obtaining normalized and weighted LCIA results that can be summed up to a single-value overall impact indicator.

5.1.2.5. Interpretation of the Results

The interpretation phase has two main purposes. During the iterative steps, the interpretation phase serves to steer the work towards improving the LCI model to meet the needs derived from the study goal. Mainly, the interpretation phase is useful to derive robust conclusions and - often - recommendations regarding the study performed.

Life cycle interpretation is the phase of the LCA where the results of the other phases are hence considered collectively and analysed in the light of the achieved accuracy, completeness and precision of the applied data, and the assumptions, which have been made throughout the LCI study.

5.2. SOCIAL LIFE CYCLE ASSESSMENT METHODOLOGY

5.2.1. REFERENCE STANDARDS

The Social Life Cycle Assessment (sLCA) to be developed in this study will be based on internationally recognised standards, primarily the UNEP/SETAC Guidelines for Social Life Cycle Assessment of Products (2009) and the complementary 2020 Methodological Sheets. These documents provide the foundational framework for assessing the social and socio-economic impacts of products across their life cycle. Additionally, the PSILCA (Product Social Impact Life Cycle Assessment) database methodology will be used to operationalise the modelling within the OpenLCA software platform.

This combined framework enables the quantification of social risks and potential impacts by linking each life cycle process to country- and sector-specific indicators. In particular, PSILCA provides a comprehensive set of social themes—such as fair salary, working hours, child labour, health and safety, corruption, and access to basic services—which are represented through a common metric: risk hours.

The reference framework ensures transparency, comparability, and relevance of results for the stakeholders involved in the MULTICLIMACT project and supports informed decision-making throughout the planning and implementation of the RES-HVAC intervention at the Latvian demo site.

5.2.2. PHASE OF THE ANALYSIS

5.2.2.1. Goal Definition:

The main objective of the sLCA will be to identify and evaluate the potential social risks associated with the cradle-to-gate life cycle of the system under assessment. Specifically, the study will serve to:

- Assess the supply chain’s exposure to social issues such as labour rights violations, health and safety risks, or governance concerns;
- Identify risk hotspots across processes and regions;
- Support socially responsible procurement and design decisions;
- Contribute to the replicability and improvement of sustainable interventions in the built environment.

The intended application will not be comparative, and the analysis will not be used for product benchmarking or public comparison. Instead, it will be a prospective tool to guide implementation and replication.

The main audience will include relevant stakeholders such as public authorities, urban designers, engineers, policy makers, and other actors involved in infrastructure development. The findings may also inform a broader community of practitioners and researchers.

partners, public authorities, urban designers, engineers, and policy makers involved in infrastructure development. As a public deliverable, the findings may also inform a broader community of practitioners and researchers.

5.2.2.2. Scope definition:

The scope of the sLCA will follow a cradle-to-gate system boundary, which includes the upstream and core processes required to deliver and install the assessed system. The analysis will not consider the use or end-of-life phases.

The system under study will comprise:

- The manufacturing of the heating distribution system;
- The manufacturing of supporting technological components (e.g., photovoltaic modules);
- The transport of these components to the installation site;
- The installation activities, including trenching, pipe laying, electrical connections, and mounting.

The functional unit will be harmonised with the environmental LCA.

The system boundaries will be aligned with the EN 15804 standard and include both upstream (A1–A3) and construction (A4–A5) phases.

Processes will be modelled in OpenLCA by linking them to appropriate country-sector combinations in the PSILCA database.

5.2.2.3. Life Cycle Inventory (LCI) analysis:

The life cycle inventory will be constructed by collecting quantitative and qualitative data related to each process involved in the system. This will include:

- Material inputs (mass, value, or units);
- Geographic origin and manufacturing country;
- Associated transport routes and modes (e.g., road, rail, sea);
- Labour inputs and number of workers involved (when available).

Primary data will be sourced from relevant stakeholders, technical datasheets, and Environmental Product Declarations. Secondary data will be retrieved from scientific literature and technical databases to fill any gaps.

Each process will be mapped to its corresponding PSILCA sector and country profile. For each activity, the economic or physical input will be translated into working hours, enabling the model to estimate social risk exposure in terms of risk hours.

5.2.2.4. Life Cycle Impact Assessment (LCIA):

The LCIA phase will translate inventory data into quantitative indicators of social performance. It will involve the following steps:

- Classification: Each process will be assigned to relevant social themes;
- Characterisation: Based on the country-sector combinations, PSILCA will assign a qualitative risk level and calculate the associated risk hours;
- Aggregation: Total risk hours will be calculated per category and per life cycle stage to identify risk hotspots.

Some categories expected to show higher social risk may include:

- Assembly of electronic components in countries with weak labour protections;
- Extraction of raw materials such as aluminium and copper;
- Manufacturing of high-tech equipment.

In contrast, activities performed in countries with robust social regulations are expected to present lower risks.

5.2.2.5. Interpretation of the Results

Once the model is completed, results will be interpreted to:

- Highlight the most significant contributors to social risk;
- Identify potential improvements in supplier selection or sourcing strategies;
- Provide insight into the trade-offs between environmental and social performance.

Qualitative analysis will complement the numerical results, especially where data uncertainty is high. The final interpretation will support recommendations for improving the social sustainability of future interventions.

6. DEVELOPMENT OF SIMPLIFIED ENVIRONMENTAL AND SOCIAL LIFE CYCLE ASSESSMENT APPROACH FOR THE APPLICATION TO REAL HISTORICAL BUILDING

The present deliverable followed by Deliverable D11.4 aims to present the methodology and application results of the evaluation of the environmental and social impact associated to the production and installation of the RES-HVAC system at the Riga, LV demo site, using data from that will be collected from involved partners and LCI database, for which RINA has a valid license.

It is important to note that the methodology applied in this assessment is based on the full and complete system design of RES-HVAC system as declared in the Grant Agreement. However, for the practical application within WP11, the assessment will be limited to the components that are actually designed and scheduled for installation within the WP11 timeframe and in line with the overall MULTICLIMACT project timeline.

6.1. DESCRIPTION OF DEMO SITE AND INNOVATIVE SOLUTION

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 (Figure 4: *Images of air curtains and hot air blowers*)

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 (*Figure 5: Location of air curtains and hot air blowers in the dairy pavilion buildings*).

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

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 2: *Average historical data of energy consumption on the dairy Pavilion*

Table 2: Average historical data of energy consumption on the dairy Pavilion

ENERGY CONSUMPTION	HEATING (AVERAGE NUMBER FROM 2022 UNTIL 2024)	HOT WATER (AVERAGE NUMBER FROM 2021 UNTIL 2024)	ELECTRICITY (AVERAGE NUMBER FROM 2023 UNTIL 2024)
	56.1MWh/year	26.1 MWh/year	136.36 MWh/year

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 auditor developed a model with the help of which the heat consumption for heating was calculated at +10˚C and modelled it to reach +16˚C. The results are summarized in Table 3: *Existing and modelled heat consumption for heating of a dairy pavilion at different indoor temperatures*

Table 3: Existing and modelled heat consumption for heating of a dairy pavilion at different indoor temperatures

INDOOR TEMPERATURE IN THE DAIRY PAVILION, ˚C	HEATING CONSUMPTION	SPECIFIC HEAT CONSUMPTION FOR HEATING
+10˚C	52,168 kWh/year	21.8 kWh/m^2
+16˚C	175,802 kWh/year	73.5 kWh/m^2

Therefore, the heat consumption for heating of 175,802 kWh per year can be considered as a baseline. The installed heating capacity for heating at the current energy efficiency status of the building is

257 kW, cooling capacity 105 kW. 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.

The Dairy pavilion building needs to design a mechanical ventilation system, which, after the end of the MULTICLIMACT project, would be built with the funds of Riga City Municipality/JSC "Rīgas nami".

To ensure heating in the Dairy pavilion, heat is supplied from the district heating system. At the bottom of the building is a large basement floor with different technical rooms. One of these rooms is a heating substation. Figure 6: *The principal scheme of a heating substation* shows the principal scheme of a heating substation that divides heating network (primary side) from the Central market heating network (secondary couture). The heating, hot water, and ventilation systems are connected to the DH system as a secondary contour.

The secondary contour of the Central market heating networks has 5 loops with 5 heat exchangers, the total installed capacity of which is 3.37 MW. There are heating, hot water preparation and 3 loops of ventilation (compared to Figure 6: *The principal scheme of a heating substation*, which shows the principal scheme with one heat exchanger (HEX) for ventilation).

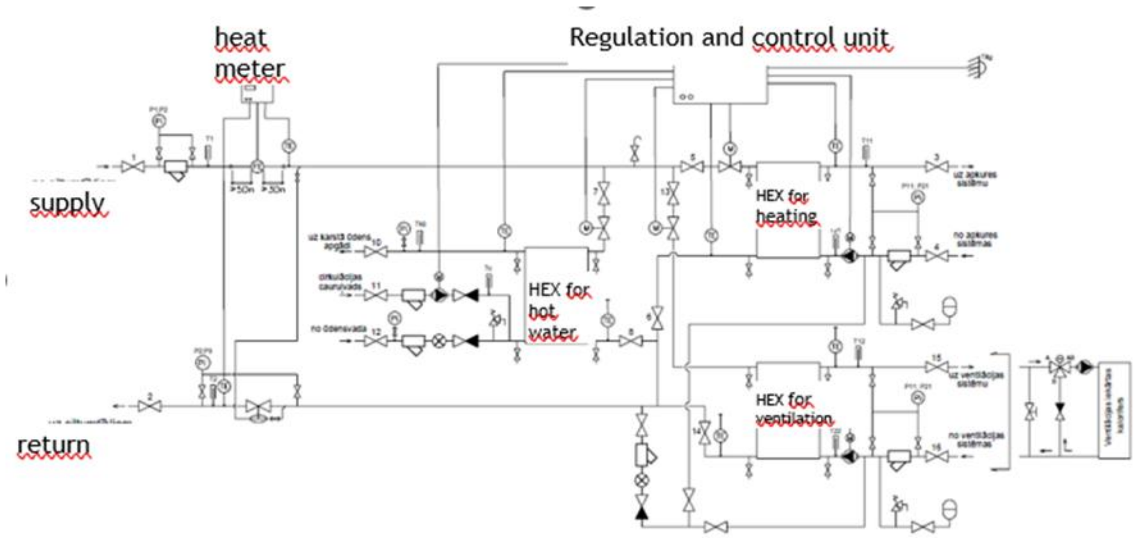

Figure 6: The principal scheme of a heating substation

The district heating (DH) system in Riga is well developed. Two types of fuel are widely used in Riga - natural gas and wood chips. In 2023, about 3,100 GWh per year heat was transferred to the networks and about 2,700 GWh per year was consumed. Figure 7: *Technologies mix in heat production in 2023* 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% heat was produced from biomass which corresponds to a sustainable principle according to Directive (EU) 2018/2001 of the European Parliament 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).

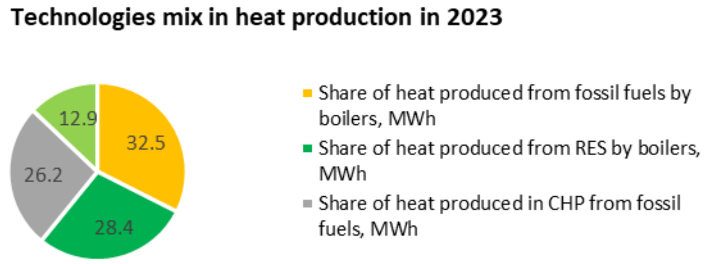

Figure 7: Technologies mix in heat production in 2023

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) (*Figure 8: Temperature regime in the DH network (Second generation district heating 2nd GDH)*.). 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 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.

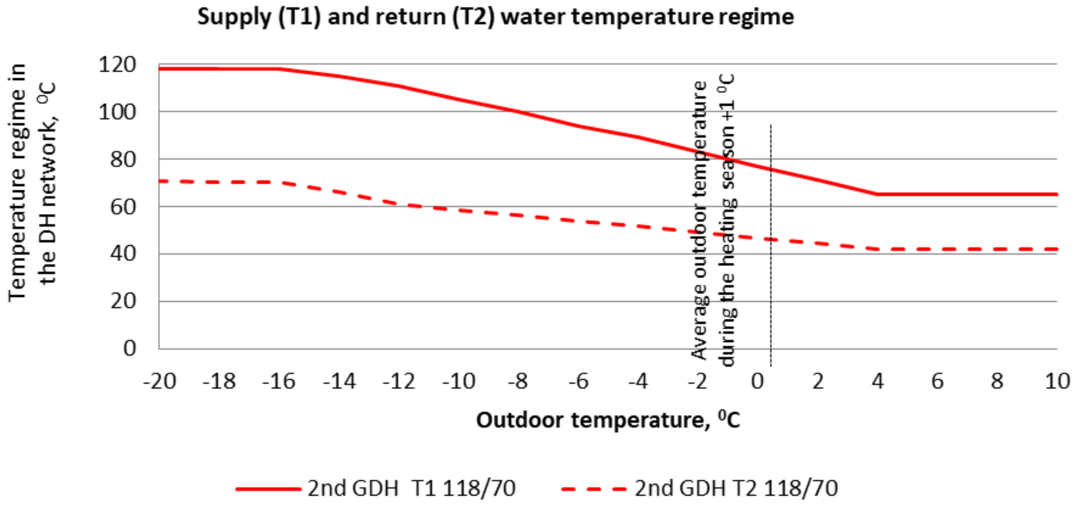

Figure 8: Temperature regime in the DH network (Second generation district heating 2nd GDH).

Given that the Uponor system offers a low-temperature underfloor heating solution using a maximum 39°C flow temperature, the return water from the district heating (DH) system could have been utilised as the heat carrier. This approach offers the advantage of increased efficiency on the heat production side of the DH.

To ensure the required constant temperature for the Uponor underfloor heating solution during the whole heating season, additional equipment (heat exchanger or other) will have to be installed. The additional heating scheme must be supplemented with other equipment, such as pumps, an automatic control system or a more advanced version of the so-called Building Management System (BMS). At the current stage of the project, design work has not been carried out and this equipment has not been identified.

The construction of the existing basement floor load-bearing slab:

- The existing basement floor load-bearing slab (with thickness of 150 mm), which is supported by the foundation structure and a column network, is designed as a monolithic reinforced concrete slab with steel beams (concreted double “T” profile bearing beams). The beams are arranged with a step of ~3 m and are supported on concrete cushions at the top of the columns.
- The basement floor construction of the Dairy pavilion is divided into nine equal areas with deformation joints, where one area covers an area of ~24 m x 11.3 m (*Figure 9: The principal scheme of the existing floor load-bearing slab division into nine areas combined with ground floor plan with the new floor compensation seams*).
- Between the nine floor construction areas in the longitudinal direction of the pavilion, deformation joints are formed in the concrete structure, while in the transverse direction, a deformation joints are created with two adjacent double “T” profile beams.

Measurements made during the technical inspection:

- There was a scan performed for the steel reinforcement of the monolithic reinforced concrete slab, determining the placement and step of the reinforcement elements. A control exposure was created, and the exposed reinforcement was measured to determine the diameter of the reinforcement and its installation depth (concrete protective layer).
- There were openings made in the reinforced concrete slab by cutting off concrete to the extent necessary to allow measurements of the steel beam geometry. During the measurements, it was concluded that the profile of the concreted steel double “T” beam corresponds to the 23B1 profile (according to GOST 26020-83).

Conclusion concerning the existing basement floor load-bearing slab:

- In general, at the time of the inspection, no damage was found to the monolithic reinforced concrete floor in the building that would significantly affect the overall mechanical strength and stability of the structure or threaten the operational safety of the pavilion, therefore, the technical condition of the basement floor is currently generally considered satisfactory, but with a pronounced tendency for the technical condition to deteriorate.

Recommendations concerning the existing basement floor load-bearing slab:

- To ensure the longevity of steel elements, it is necessary to dismantle the flaked concrete and protective layer, cleaning the beams and reinforcement. Once this is done, the metal elements must be treated with anti-corrosion agents, and a new concrete protective layer must be created. When cleaning the beams, it is necessary to assess whether the steel elements can be preserved or whether individual beams must be replaced.
- The existing basement floor load-bearing slab – in areas where utility networks cross the slab structure, it is necessary to clean corroded reinforcement, carry out anti-corrosion treatment and restore the concrete protective layer. Before carrying out this work, the causes of moisture in these areas must be eliminated.
- The existing basement floor load-bearing slab – it is necessary to carry out sealing works for insuring hermeticity in the areas of deformation joints, preventing moisture migration from the first floor to the basement through the deformation joints formed in the floor structure.
- All the works recommended is going to be carried out by Riga City Municipality/JSC "Rīgas nami" within another renovation project - the fortification of the building’s frame steel structure.

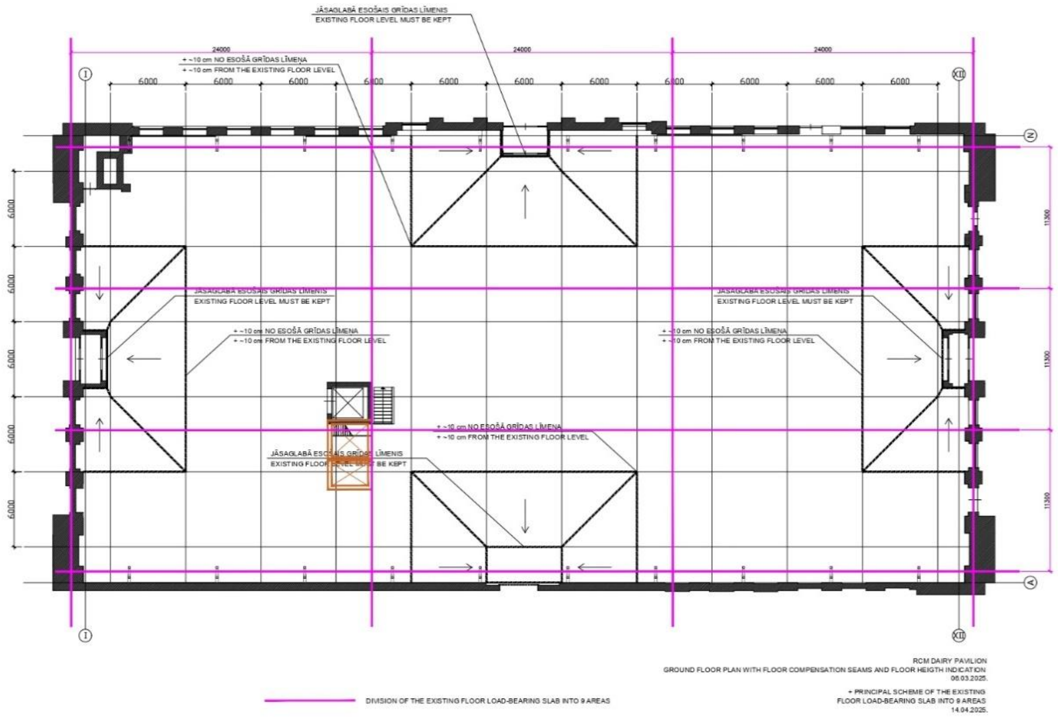

Figure 9: The principal scheme of the existing floor load-bearing slab division into nine areas combined with ground floor plan with the new floor compensation seams

The construction of the floor after the renovation in the scope of MULTICLIMACT:

- The existing floor load-bearing slab will be kept and renovated as recommended.
- On top of the existing floor load-bearing slab the necessary layers of the new floor with insulation, concrete and other materials will be installed (*Figure 10: The cross section of the floor construction with the new floor layers*).

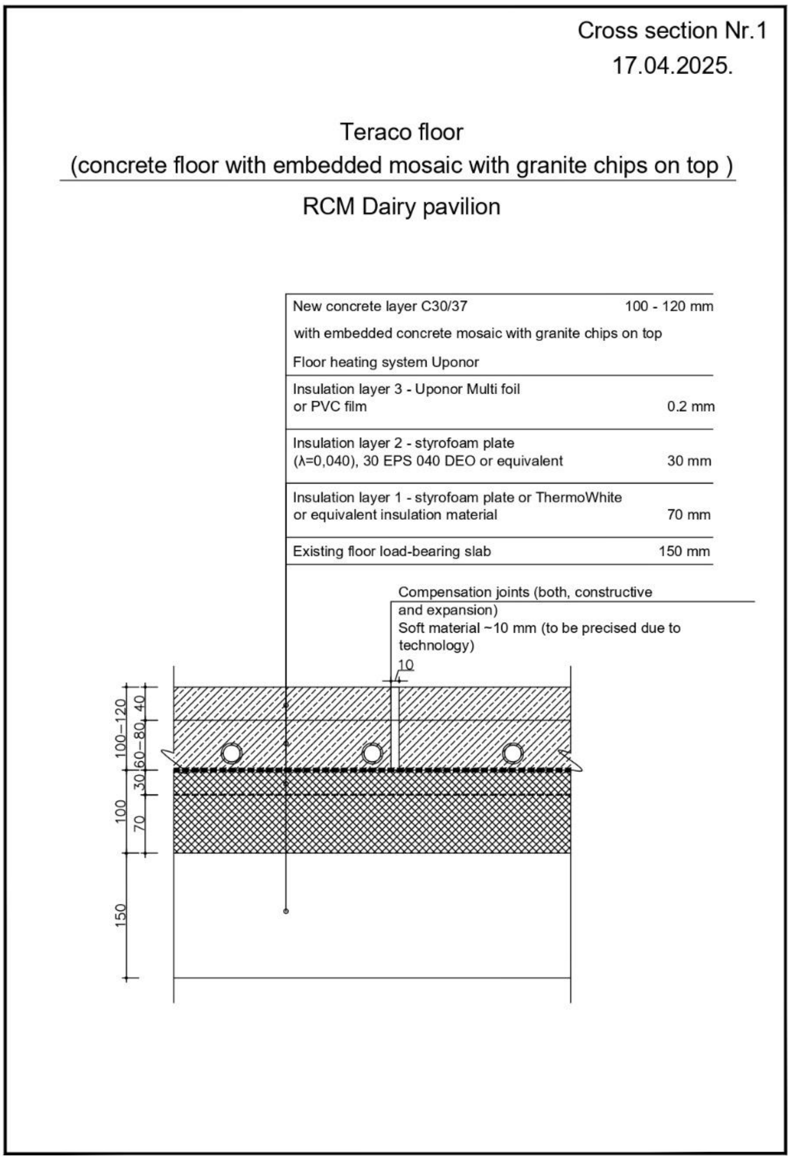

Figure 10: The cross section of the floor construction with the new floor layers

6.2. DESIGN OF LOW TEMPERATURE HEATING SOLUTIONS

In this task we designed the preliminary low-temperature heating system 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 3379 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 11: *Uponor Classic Wet Underfloor-Heating*) 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, 20×2.0 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 11: Uponor Classic Wet Underfloor-Heating

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.

6.2.1. UNDER FLOOR HEATING SYSTEM DESIGN

The UFH system is supplied by return water from the district-heating network at 42–46 °C, which is tempered to a 39 °C supply temperature in a low-temperature substation. The main loop operates at 37,745 kg/h and connects seven manifold stations (M.01–M.07). Each manifold serves 15–19 individual circuits using 20 × 2.0 mm Comfort Pipe PLUS.

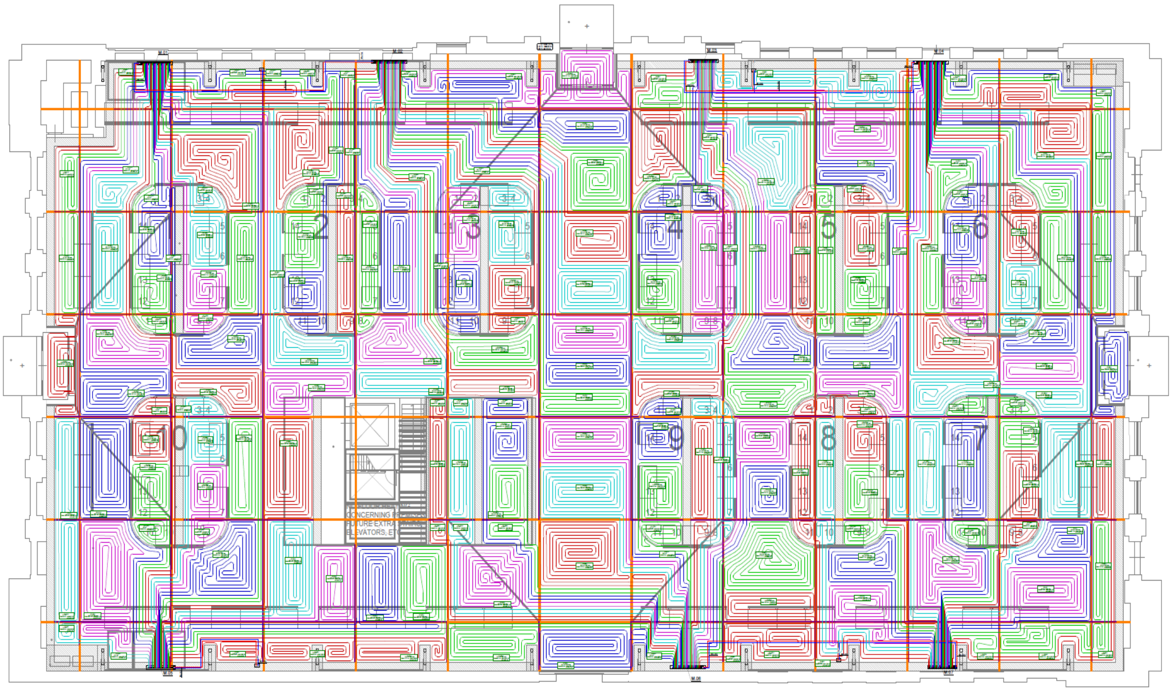

Figure 12: Single line diagram of the underfloor heating solution

Hydraulic performance is maintained with an available pressure head of 111.5 kPa on the main loop, while manifold-level pressure drops range from 66.8 kPa at M.06 to 90.0 kPa at M.05. Isolation valves, flow meters, and differential-pressure gauges are included at each manifold to support balancing and commissioning. Per-manifold design parameters confirm compliance with the thermal load requirements. The circuits achieve design ΔT values of 5.0–5.3 K, with flow rates between 4845 and 6207 kg/h and total loop lengths of 1450–1893 m. These data confirm that all circuits remain within Comfort Pipe PLUS installation limits while ensuring reliable load coverage.

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Source/Source: 1	Application: Heating systems/Cooling systems		Medium: Water
Temperatures θs,H and θr,H [°C]	39.0	33.8	
Temperature source for control circuit Source/1			
Temperatures θs,H and θr,H [°C]	39.0	33.8	
Required heating output Φreq,H [W]	199532		
Obtained heating output ΦH [W]	207643		
Heat capacity lost ΦOS,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**	**ΦH**	**ΦOS,H**	**θr,H**	**ΔθH**	**m**	**Δpmin**	**Δp**	**Ltot**
			W	**W**	**°C**	**K**	**kg/h**	**kPa**	**kPa**	**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 13: key manifold circuit parameters

6.2.2. BILL OF QUANTITIES

The bill of quantities (BOQ) specifies all Uponor components required for the Classic wet under-floor-heating installation. It includes: 11677 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 14: 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.

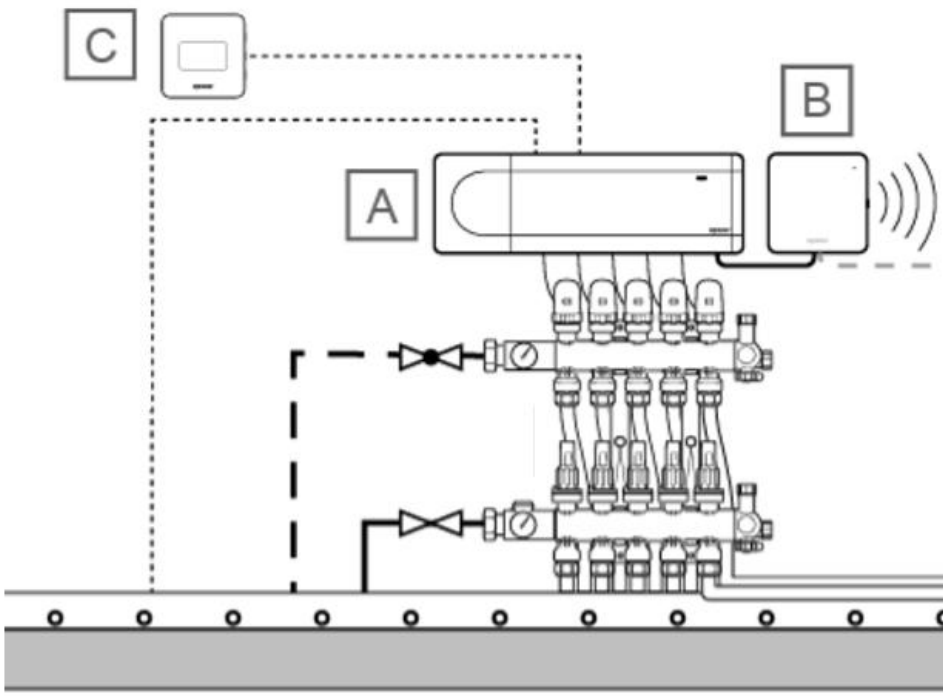

Figure 14: Underfloor heating manifold with vario actuators and Uponor's matrix controls

6.3. "CRADLE-TO-GATE" ENVIRONMENTAL LIFE CYCLE ASSESSMENT APPROACH

6.3.1. GOAL OF THE STUDY

For this analysis the goal of the assessment is described as follows:

- **Purpose of the study**: main purpose of this document is to evaluate the environmental impacts of the installation of full operational of RES HVAC system in the REGA cultural heritage site.
- **Reason for conducting the study, decision -context:** the reason why this LCA study was carried out is related to the quantification of the environmental performance of the intervention on the REGA site within MULTICLIMACT context in particular the installation of new RES-HVAC system. The study does not influence the beneficiary in any decision but is useful for evaluating the environmental impacts of the intervention;
- **Target audience:** the audience of this LCA study is represented by the MULTICLIMACT Consortium and the previously highlighted target group;
- **Comparison intended to be disclosed to the public:** the LCA analysis does not include a comparison. The results is disclosed also to the public as D8.3 is public deliverable as presented the MULTICLIMACT Grant Agreement.

6.3.2. SCOPE OF THE STUDY

The final system configuration includes only the heating solution and the photovoltaic (PV). Currently only the PV panels and the underfloor solutions are designed and confirmed as part of the final solution. The equipment that will be installed to connect the Uponor solution to DH networks has not been designed yet. The ventilation and air conditioning components are still under evaluation and may not be included in the scope of this analysis.

Therefore, the analysed system will consist of:

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- the manufacturing and transport of complete heating solution (pipelines and equipment) system to the demo site
- the manufacturing of PV panels and transport to the demo site location
- the installation of the heating system and PV system

System boundary: as outlined in the "Deliverable D2.3 - LCC, LCA, sLCA for planning and designing of resilience enabling interventions on the built environment at multiple scales", considering the analysed system or product in the context of intervention in the built environment, a reference was made to the EN 15804 standard to define the system boundary, for this case, a reference was made to the following stages:

- Production stage includes the modules A1, A2 and A3 that can be declared as one aggregated module A1 - 3:
  - A1 - raw material supply, including processing of secondary materials
  - A2 – transport of raw material and secondary material to the manufacturer
  - A3 – manufacture of the construction products, and all upstream processes from cradle to gate
- Construction process stage including modules A4 and A5:
  - A4 – transport of construction products to the building site
  - A5 – the building installation/construction
- Use stage related to building fabric and including the modules B1, B2, B3, B4 and B5:
  - B1 – use the installed product, service or appliance
  - B2 – maintenance of the product
  - B3 – repair of the product
  - B4 – replacement of the product
  - B5 – refurbishment of the construction product
- Use stage related to operation of building and including the modules B6 and B7
  - B6 – operational energy
  - B7 – operational water use
- End-of-life stage including the module C1, C2, C3 and C4
  - C1 – demolition of the building/building product
  - C2 – transport of the demolition waste comprising the end-of-life construction product to waste processing facility
  - C3 – waste processing operations for reuse, recovery or recycling
  - C4 – final disposal of end-of-life construction product

The life cycle model includes also the benefits and loads beyond the system boundary, module D corresponding to reuse, recovery and recycling potentials evaluated as net impacts and benefits. The principle of **module D** applied for construction products and materials

For the purpose of different data quality rules and for the presentation of results, the system boundary is divided into three different stages (Figure 15: *System Boundaries*):

- Upstream processes (from cradle-to-gate)
- Core processes (from gate-to-gate)
- Downstream processes (from gate-to-grave)

The scope of this study is to perform a cradle to gate LCA from raw materials extraction and production, pilot realization and process operation, up to the production of the final product. Figure 15: *System Boundaries* illustrates the system boundaries and the covered modules of the LCA analysis.

The impact of these products on human health, natural environment and natural resources caused by interventions between Technosphere and Ecosphere during operations is assessed against all relevant impact categories resulting from the analysis

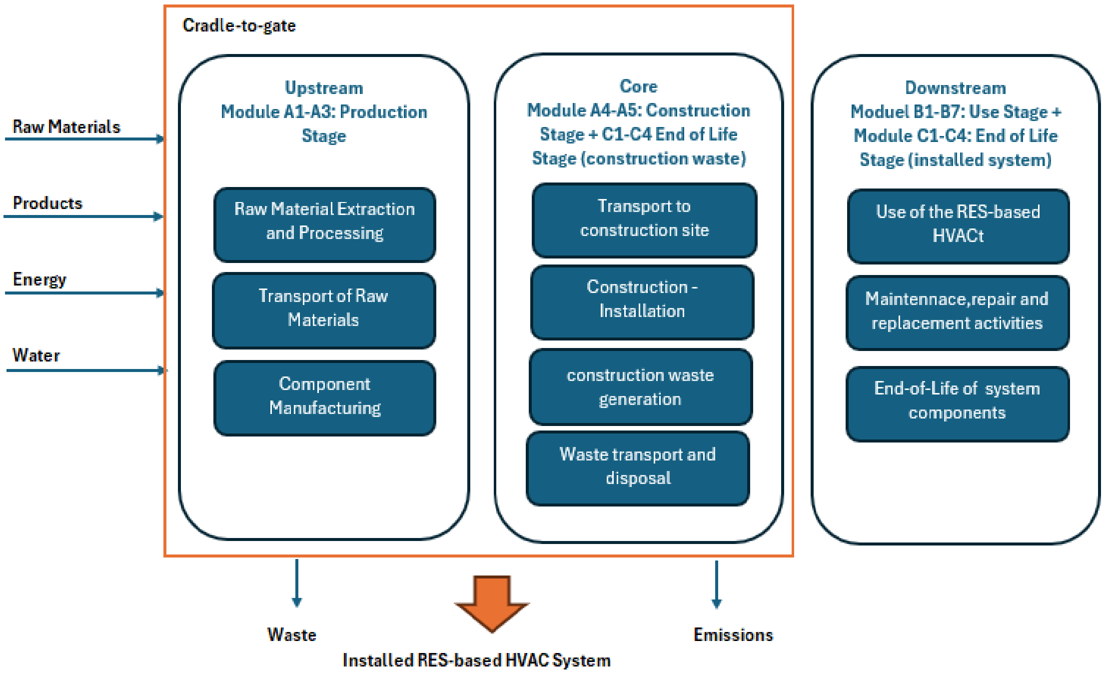

Figure 15: System Boundaries

The activities are divided as follows:

The "upstream processes" that make up the background system are:

- Extraction, transport and manufacturing of raw materials
- Generation of electricity from primary and secondary energy resources, also including their extraction, refining and transport for Modules A1 and A3
- Manufacturing of the products (RES-HVAC system components)
- Packaging of the products

The "core processes" of the foreground system are:

- Transport of materials and products from the factory gate to the "building" site
- Transport of materials, products, waste and equipment within the site
- Installation of the products into the "building"
- Energy and water use during construction
- Production, transportation and waste management of products and materials lost during the construction and installation process

According to the "cut-off" definition, for this study flows will be considered "not relevant" if their impacts on overall environmental impact are estimated to be below a certain threshold percentage, set at 5%. Additionally, the exclusion of certain energy and mass flow will consider also the data availability and data quality.

The cut-off criteria for initial inclusion of inputs and outputs, along with assumptions regarding these criteria, will be clearly described.

Functional unit: At this stage the final configuration of the solution for Latvian demo site is not completed to be able to clearly define the functional unit. A preliminary functional unit can be **"thermal energy delivered per one year".** Other functional units may include "one complete operational RES-Heating system installed at the demo site" or as "1 m^2 of area heated" The final definition of the functional unit will be determined based on the updated information regarding the final installation of the solution, in alignment with the project's goal and system boundaries.

As previously mentioned, within the MULTICLIMACT project, it is possible that not all RES-HVAC components will be installed. Therefore, the analysed system may be limited to the heating distribution pipes and the PV panels.

Impact categories: for the selection of the impact categories reference is made to The Sixth Environment Action Program of the European Community 2002-2012 (European Parliament and the Council 2002) and the EN 15804:2012+A2:2019 Annex C. A preliminary list of Impact categories, and indicators are presented in Table 4: *Environmental Life Cycle Assessment Impact Category Indicators*

Table 4: Environmental Life Cycle Assessment Impact Category Indicators

IMPACT CATEGORY	INDICATOR	UNIT	ORIGINAL REFERENCE MODEL
Climate change	Global Warming Potential total (GWP-total) [9]	$kgCO_2eq$	Baseline model of 100 years of the IPCC based on IPCC 2013
Climate change	Global Warming Potential total (GWP-fossil)	$kgCO_2eq$	Baseline model of 100 years of the IPCC based on IPCC 2013
Climate change	Global Warming Potential total (GWP-biogenic)	$kgCO_2eq$	Baseline model of 100 years of the IPCC based on IPCC 2013
Climate change	Global Warming Potential total (GWP-LULUC)	$kgCO_2eq$	Baseline model of 100 years of the IPCC based on IPCC 2013
Ozone Depletion	Depletion potential of the stratospheric ozone layer (ODP)	Kg $CFC_{-11}eq$	Steady-state ODPs, WMO 2014
Acidification	Acidification potential Accumulated Exceedance (AP)	mol H^+eq	Accumulated Exceedance, Seppala et al. 2006, Posch et al., 2008
Eutrophication aquatic freshwater	Eutrophication potential, fraction of nutrients reaching freshwater end compartment (EP-freshwater)	Kg PO_4eq	EUTREND model, Struijs et al, 2009b
Eutrophication aquatic marine	Eutrophication potential, fraction of nutrients reaching freshwater end compartment (EP-marine)	Kg N eq	EUTREND model, Struijs et al, 2009b
Eutrophication aquatic terrestrial	Eutrophication potential, Accumulated Exceedance (EP-terrestrial)	mol N eq	Accumulated Exceedance, Seppala et al. 2006, Posch et al., 2008
Photochemical ozone formation	Formation potential pf tropospheric ozone (POCP)	Kg NMVOC eq	LOTOS-EUROS, Van Zelm et al., 2008
Depletion of abiotic resources - minerals and metals	Abiotic depletion potential for non-fossil resources (ADP – minerals & metals)	Kg Sb eq	CML 2002, Guinée et al.,2002, and Van Ores et., 2002.

[9] GWp-total is the sum of GWP-fossil, GWP-biogenic and GWP-LULUC

IMPACT CATEGORY	INDICATOR	UNIT	ORIGINAL REFERENCE MODEL
Depletion of abiotic resources - fossil fuels	Abiotic depletion potential for fossil resources (ADP-fossil)	MJ, net calorific value	CML 2002, Guinée et al.,2002, and Van Ores et., 2002.
Water use	Water (user) deprivation potential, deprivation weighted water consumption (WDP)	m^3 world eq deprived	Available WAter Remaining (AWARE) Boulay et al., 2016

All the substances generated during the life cycle of the products are quantified and then combined (i.e., characterized) by using characterization factors, which convert the single substance in an equivalent one. The characterization factor is equal to 1 for the substance that represents the impact category (e.g., the characterization factor is equal to 1 for carbon dioxide substance for the quantification of the "Global Warming" impact category). The characterization factors are defined according to the selected LCIA methodology.

6.3.3. LIFE CYCLE INVENTORY ANALYSIS

Life cycle inventory attribution modelling principles are used in this analysis. Using measurable data along the supply chain in relation to manufacturing of the solutions and the installation activities.

An example of inventory table will be defined based on collected data from Partners. Table 5: Data collection checklistsprovides an example of all input and output flows data categorized by process step to be collected, including:

- Flow: Description of each flow.
- Amount and Unit: Quantitative details of each flow.
  Distance and means of transport: Information related to transportation logistics

Table 5: Data collection checklists

INPUT/OUTPUT	AMOUNT	UNIT	DISTANCE	MEANS OF TRANSPORT	SOURCE
Manufacturing of Heating system (pipelines + equipments)					
Manufacturing of PV system (panels and electrical components					
Installation of Heating system and PV panels – Construction activities					

It is important to highlight that the pipelines for the heating system, designed by Uponor, are covered by an EPD "EPD HUB, HUB-0562: publishing date 7 July 2023, last updated on 7 July 2023, valid until 7 July 2028". In cases where detailed manufacturing process data is limited or unavailable, we will refer to the environmental impacts reported in the EPD for each life cycle stage as a reliable data source.

To evaluate the quality of the data, in terms of reliability of source, completeness, temporal coverage, geographical coverage, technological covered. The matrix[10] below presents to criteria will be adopted for this study.

Table 6: Matrix of criteria for assessing data quality

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Reliability of source	Verified data based on measurement	Verified data partially based on assumptions or non-verified data based on measurements	Non-verified data, based on assumptions	Qualified estimates 8e.g. by industrial assumptions)	Non-qualified estimate or unknown origin
Completeness	Representative data from a sufficient sample of sites over an adequate period to even out normal fluctuation	Representative data from a smaller sample of sites but for adequate periods	Representative data from an adequate number of sites but from shorter periods	Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods	Representativeness unknown or incomplete data from a smaller number of sites and/or from shorter periods
Temporal coverage	Less than 1 year of difference to year of study	Less than 2 years difference	Less than 5 years difference	Less than 10 years difference	Age of data unknown or more than 10 years of difference
Geographical coverage	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar condition	Data from area with slightly similar conditions	Data from unknown area or with different conditions
Technological coverage	Data from enterprises, processes and materials under study	Data from processes and materials under study from different enterprises	Data from processes and materials under study but from different technology	Data on related processes or materials but same technologies	Data on related processes or materials but different technology

6.3.4. LIFE CYCLE IMPACT ASSESSMENT

In this preliminary study, RES-HVAC system production and installation process through MULTICLIMACT Project is analysed using a Cradle-to-Gate approach. LCIA assessment will be done using the specialized software Sphera's LCA for Experts (formerly GaBi) integrated with the Ecoinvent database, for which RINA-C holds a regular license.

[10] Weidema, B. P., & Wesnaes, M. S. (1996). Data quality management for life cycle inventories—an example of using data quality indicators. Journal of cleaner production, 4(3-4), 167-174.

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Sphera's LCA for Experts (formerly GaBi) is a modelling and reporting software tool developed by Sphera (formerly known as "Thinkstep" and "PE International") that facilitates the modelling of process chains. It allows users to describe a production technology, product, or service through its input and output flows. Users can define their selected technology or product by incorporating structural information and creating parts with material inventories and production processes.

The software provides access to existing processes and flows in its internal databases, or users can define new items based on experimental values or literature data. Once the system is defined in terms of involved processes and mass and energy flows, various Impact Assessment Methodologies can be applied to derive results.

Additionally, the Swiss Ecoinvent database is available, featuring thousands of LCI entries across diverse sectors such as agriculture, energy supply, transport, biofuels, biomaterials, chemicals, construction materials, metals processing, electronics, and waste treatment.

To be noted that RINA-C will assess the feasibility of using Excel spreadsheets, as an alternative to Sphera's LCA for Experts software, for converting input-output flows into environmental impact data. This will be done using characterization factors from the Ecoinvent database.

In the LCIA phase, RINA-C will systematically evaluate potential environmental impacts based on the LCI results. The steps involved will include:

- **Classification**: Assigning LCI results to relevant impact categories such as climate change, acidification, eutrophication, etc.
- **Characterization**: Calculating category indicator results by converting LCI results into common units using characterization factors.

This structured approach will enable RINA-C to derive meaningful insights into the environmental performance of both conventional and MR-assisted hydrogen production processes.

6.3.5. INTERPRETATION OF RESULTS

At this stage, the LCA results will be evaluated by highlighting the breakdown across different life cycle stages and processes, identifying key impact hotspots, and assessing the potential for improvement in terms of data collection and data quality.

6.4. "CRADLE-TO-GATE" SOCIAL LIFE CYCLE ASSESSMENT APPROACH

6.4.1. GOAL OF THE STUDY

The main goal of the sLCA to be carried out for the Latvian demo site is to identify and evaluate potential social risks associated with the supply chain of the RES-HVAC system. The system integrates renewable energy-based heating (e.g. Uponor Ecoflex Thermo Twin pipes) and electricity generation (photovoltaic panels), to be installed at the Riga Central Market.

This prospective sLCA aims to support socially responsible decision-making by highlighting supply chain elements—materials, countries, sectors—where social risks such as low wages, poor working conditions, or human rights violations are more likely to occur. These insights will be relevant not only for the initial deployment but also for future replication activities in other sites.

The assessment will be conducted using the PSILCA database within the OpenLCA software environment, ensuring methodological alignment with UNEP/SETAC guidelines and transparency in indicator calculation.

6.4.2. SCOPE OF THE STUDY

The scope of this study is to conduct a cradle-to-gate Social Life Cycle Assessment (sLCA), covering all stages from raw material extraction and processing, through pilot implementation and operational activities, up to the manufacturing of the final product.

The final system configuration currently includes only the heating solution and the photovoltaic (PV) components. At this stage, only the PV panels and the underfloor heating system have been designed and confirmed for implementation. The equipment required to connect the heating system to the district heating (DH) network has not yet been defined. Ventilation and air conditioning components are still under consideration and may fall outside the scope of this analysis.

Accordingly, the system under assessment will include:

- The manufacturing and transportation of the complete heating system (including pipelines and associated equipment) to the installation site;
- The manufacturing and transportation of PV panels to the installation site;
- The installation of both the heating and PV systems.

The **functional unit** will be consistent with the environmental LCA and is expected to be either:

- Thermal energy delivered per one year
- One fully installed RES-HVAC system, or
- One square metre of installed system surface.

The study will focus on **potential social risks** rather than actual impacts, and no comparative assertions will be made. Only upstream and core life cycle stages (modules A1–A5) will be included.

6.4.3. LIFE CYCLE INVENTORY ANALYSIS

The inventory phase will involve identifying all relevant processes and collecting data on:

- The type and quantity of materials and components involved;
- The country of origin and sector for each process;
- The value or weight of each input, to estimate economic flows and associated labour hours.

The main foreground processes include:

- Heating pipe production by Uponor in Finland;
- PV panel production (assumed in Germany or China depending on supplier);
- Long-distance and regional transport;
- On-site installation in Latvia.

Background processes such as raw material extraction (e.g., copper from Chile, silicon from China) will also be included where feasible, using proxy sectors in PSILCA.

Each process will be mapped in OpenLCA to a sector-country pair in PSILCA, which links it to a dataset of social indicators. The data inputs (e.g., economic value in USD) will be used to calculate the number of **working hours**, which are then associated with different levels of **social risk** (from low to very high) depending on the process characteristics.

6.4.4. LIFE CYCLE IMPACT ASSESSMENT

In the LCIA phase, the social risks identified in the inventory will be quantified using PSILCA's structure of **risk hours**. This unit measures the amount of labour time exposed to a certain risk level for each social indicator.

Key impact categories include:

- **Labour rights and decent work**: risks related to low wages, excessive working hours, lack of freedom of association;
- **Health and safety**: risk of occupational accidents or hazardous working conditions;
- **Human rights**: child labour, forced labour, discrimination;
- **Community and societal well-being**: impacts on local access to resources, corruption levels, or governance structures.

For each process, OpenLCA will calculate the total risk hours per indicator, allowing comparison across components and life cycle stages. For instance:

- PV panel assembly may show high risk hours for fair wage and working time;
- Raw material extraction may score high for human rights concerns;
- Installation in Latvia is expected to have low risk levels due to strong labour regulation.

The LCIA will help identify risk hotspots, guiding possible improvements such as switching suppliers, selecting alternative materials, or applying stricter procurement standards.

6.4.5. INTERPRETATION OF RESULTS

The interpretation phase will consolidate the findings of the inventory and impact assessment, with the goal of understanding:

- Which materials, components, or countries contribute most to total social risk;
- Which social themes (e.g., wages, health and safety) are most critical across the system;
- Where trade-offs might exist between social, environmental, or economic performance.

Special focus will be placed on high-risk processes such as:

- PV module manufacturing, particularly if sourced from regions with weak labour protections;
- The extraction of raw materials like copper or silicon in high-risk countries;
- Transport logistics with long global supply chains.

Conversely, processes within the EU (e.g. installation in Latvia, manufacturing in Finland) are expected to show minimal risk exposure. Where data uncertainty or modelling assumptions significantly influence results (e.g., lack of supplier-specific data), qualitative interpretation will supplement quantitative results. This will ensure that conclusions remain robust and practically useful.

Ultimately, the interpretation will offer actionable recommendations to:

- Improve supply chain transparency;
- Strengthen procurement criteria;
- Reduce exposure to socially sensitive processes in future replication of MULTICLIMACT interventions.

7. METHODOLOGY FOR COMPARATIVE ANALYSIS OF ACHIEVED BENEFITS

This section presents the methodological approach will be followed to assess the environmental and social achieved benefits, as well as to identify any potential limitations or adverse impacts. The LCA models previously described are based on a cradle-to-gate approach for the designed solution, the evaluation of achieved benefits focuses specifically on the use stage (operational phase). Given the possibility that only a part of the RES-HVAC system such as the pipe heating system will be fully designed and installed within the MULTICLIMACT period, the assessment will be limited to the components and scope effectively delivered under WP11.

A comparative analysis will be conducted between the environmental and social performance of the existing conventional HVAC system and the MULTICLIMACT solution during the use phase within the defined boundaries.

The **environmental impacts** will be assessed mainly in terms of energy consumption and associated greenhouse gas (GHG) emissions using public average emissions and operational data or modelling results.

The analysis will start by defining a common unit of analysis to ensure comparability and in alliance with the project goals between the conventional HVAC system and the MULTICLIMACT solution. Possible reference units suitable for this assessment may include, for example, kWh of energy consumed per square meter per year (kWh/m²/year) or GHG emissions per square meter (kg CO_2-eq/m²) over the use phase.

A data collection checklist will be developed to gather all relevant information for both scenarios including:

- Energy consumption and energy sources associated with the current (baseline) HVAC system;
- operating hours;
- energy performance data, including measured consumption from energy monitoring systems, utility bills, or building energy audits.

In parallel, equivalent data will be collected or modelled for the MULTICLIMACT scenario, specifically:

- The quantity and type of energy required to meet the building's heating and cooling demands;
- The expected energy efficiency improvements introduced by the MULTICLIMACT solution;
- Energy source profiles, distinguishing between electricity, renewables, or other fuels.

The collected data will be used to evaluate the changes in energy performance and associated GHG emissions and if possible other environmental indicators between the conventional system and MULTICLIMACT solution during the use phase.

For what concerns the social impacts of the MULTICLIMACT solution will be mainly assessed through the development of a sLCA. The analysis will focus on the portion of the RES-HVAC system effectively installed and operational within the project timeframe and will compare its performance to that of the baseline HVAC system currently in place. Social indicators relevant to the use phase, such as occupational health and safety, fair labour conditions for maintenance staff, and community-level aspects like access to reliable, clean energy, will be considered to the extent that data availability allows. The assessment will use the same functional unit defined for environmental evaluation to ensure consistency. For both the baseline and the MULTICLIMACT scenarios, qualitative and semi-quantitative data will be collected regarding system operation, labour intensity, and the socio-economic context of energy provision. The PSILCA framework will enable the estimation of potential social risks associated with ongoing activities and services, expressed in terms of risk hours across selected categories. Differences in labour conditions, local employment effects, and broader social outcomes will be analysed to highlight the relative benefits or limitations of the intervention. Where direct measurement or modelling is not feasible, expert judgement and qualitative data will be used to supplement the interpretation.

8. OUTPUTS FOR OTHER WPS

Deliverable 8.3 provides the method, and requirements will be used to assess the environmental and social impact of the for the Latvian demo site that will be implemented with WP11 activities.

D8.3 is the reference for data collection activities within WP11 and WP15. The results of the assessments will be integrated into the D11.4 in alliance with the MULTICLIMACT overall approach, where:

- WP8 focuses on the development of planning and design methods, particularly focusing on their demonstration in real contexts;
- WP11/WP15 focus on testing and demonstrating the MULTICLIMACT framework in the field, working on the four large demonstration sites.

9. CONCLUSION

This deliverable has presented the methodological framework for assessing the environmental and social impacts of the innovative RES-HVAC system implemented at the Latvian demo site within the MULTICLIMACT project. The combined use of eLCA and sLCA will enable a comprehensive sustainability evaluation of the solution, providing insight into both environmental and socio-economic dimensions relevant for future replication at different scales.

Both the eLCA and sLCA will adopt a cradle-to-gate perspective, considering the life cycle stages from raw material extraction, component manufacturing, and transport, up to the delivery and installation of the system. This scope reflects the current stage of implementation and aligns with the data available from the demo site. While the environmental assessment will focus on indicators such as energy use, greenhouse gas emissions, and resource depletion, the social assessment will investigate potential social risks and benefits across the supply chain using the PSILCA database and OpenLCA software, in line with UNEP/SETAC guidelines.

The preliminary analysis indicates that the MULTICLIMACT solution may lead to significant improvements over the baseline, not only in terms of reduced environmental impacts but also in terms of lower social risk exposure.

Given the partial implementation of the RES-HVAC system foreseen within the project timeframe, the assessment will be limited to those components effectively delivered under WP11. Nevertheless, the methodological structure defined in this task will ensure that both environmental and social performance can be robustly assessed, using a consistent functional unit and harmonised assumptions.

In the next steps, further data collection and validation will be carried out in collaboration with technical partners, allowing for a comparative evaluation between the baseline and the MULTICLIMACT system during the operational phase. This will support the demonstration of achieved benefits in terms of energy performance, emissions reduction, and social value creation, strengthening the replicability of the MULTICLIMACT approach.

10. LITERATURE /REFERENCES

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