Mid-term Scientific Report of the Project

Project title: **Sustainable management of the urban heating system under EU Fit for 55 package: research and development of the methodology and tool**

1. Scientific excellence

The *European Green Deal* (GD) and the *Fit for 55* package have set ambitious targets for reducing greenhouse gas (GHG) emissions. These initiatives require municipalities, which are responsible for sustainable development of their territories, to ensure strategic management of urban heating systems; this includes significantly improving heating efficiency, undertaking massive renovations of residential and commercial buildings, and retrofitting urban heat generation and supply systems.

Each urban heating system is unique, and managing it requires a flexible pre-design assessment that considers the potential benefits of different renovation projects. This assessment should adapt to changing funding and project tender rules. The aim of this research is to develop a user-friendly methodology and innovative tool for the sustainable management of urban heating systems. This tool will enable rapid, accurate, and objective analysis during the pre-design stage, allowing for the evaluation and comparison of various heating system renovation options in a given area in terms of their efficiency.

The developed management methodology and tool will provide insights into several key aspects, including achievable heat consumption and primary energy savings, reduction of CO_2 emissions, changes in heating tariffs and costs, and necessary investments. Achieving these goals will contribute to significant scientific advancements in management science, climate policy evaluation, and technological know-how in data processing.

The research process consists of multiple activities, numbered 1-20. Number of activities have already been completed as part of the mid-term stage, leading to the development of a first test version of the methodology and tool as outlined in the work plan. Results of these activities ar described in following sctions of the ccurrent Report. Ongoing work will continue to refine and improve the results as an agile business process improvement methodology is applied for the research implementation.

Activity 1. Study of competences

The large-scale renovation and retrofitting of urban heating systems necessitate multi-level management, requiring strong cooperation among all levels of governance to establish an integrated regulatory environment and facilitate the process at national, regional, and local levels. This collaboration should involve social partners, academia, the business community, citizens, and civil society.

The division of competences between EU member states and their subnational governments falls within national jurisdiction, resulting in varying national divisions of tasks, responsibilities, and functions across national, regional, and local governments, as well as different representatives from the private sector and citizens. However, the principle of subsidiarity, which serves as the main principle for dividing competences, is recognized across all EU member states. Additionally, sustainability, solidarity, and proportionality are critical principles for the successful management of the GD strategy.

The intermediate position of local governments (LGs) between higher levels of public governance and private stakeholders highlights the significance of their role in the GD. Municipalities play a crucial role in strategic development planning and decision-making, impacting not only climate change but also economic and energy sustainability within their areas. The interests of the local community and private businesses call for support in territorial and business development, as well as the reduction of energy and heating costs.

Given that the EU budget and national budgets alone cannot fully finance the process, the involvement of private sector resources, including households and entrepreneurs, becomes essential for success.

Achieving solidarity in this complex and sensitive situation requires meaningful local dialogues with entrepreneurs, NGOs, and households. LGs have the greatest competence in comparison to national governments when it comes to facilitating and consulting with the private sector, encouraging their willingness to transform habits and achieve zero-emission areas, despite the necessary investments in building renovation and retrofitting.

The European GD and the Fit for 55 package can be seen as the EU's contribution to the global Paris Agreement, which is monitored by the United Nations Environment Programme (UNEP). UNEP has recommended the division of actions and competences among stakeholders (Table 1), providing a detailed structure for accelerating the transformation of the building segment towards zero GHG emissions by different actors.

Table 1

The UNEP: important actions to accelerate transformation in buildings by different stakeholders

Levels/stakeholders	*Actions/competences*
International actors	Provide access and favorable conditions to finance data Support skills and knowledge growth
National governments	Regulate towards the achievement of zero-carbon building stock Incentivize zero-carbon building stock Facilitate zero-carbon building stock
Local governments	Implement zero-emissions building stock plans Integrate low-emissions requirements in urban planning Add requirements that go beyond the national level
Financial institutions	Adjust strategy and investment criteria for zero carbon building stock Support building renovation
Businesses	Construction and building material companies should review business models Achieve zero-carbon owned or rented building stock
Citizens	Retrofit for improved carbon footprint Tenants challenge landlords Adopt energy-saving behaviors

However, UNEP does not provide detailed mechanisms for achieving higher goals, leaving room for further exploration and implementation.

Activity 2. Study of actions in buildings

A user-friendly calculation tool was developed based on the ISO 52016-1 standard, utilizing a simplified model of the heat balance for buildings (Figure 1).

Heat transfer in buildings comprises two components: heat flux per area and per linear thermal bridges. The second component is typically significant only for buildings with very high thermal resistances in their structures or specific locations with construction joints lacking adequate insulation. For simplified calculations in typical non-renovated buildings, this component can be neglected.

Various actions are being implemented to minimize heat losses from buildings, thereby reducing related CO2 emissions. These actions primarily focus on reducing heat transfer through the building envelope and ventilation system, as well as retrofitting the technical systems within the building. The practical benefits (ΔQ_{build} in Figure 4) and costs associated with these actions may vary depending on the specific building, but for non-renovated buildings, recommended actions and best practices can be grouped as follows:

- Replacement of old windows and doors, as these elements have the most critical impact on thermal properties.

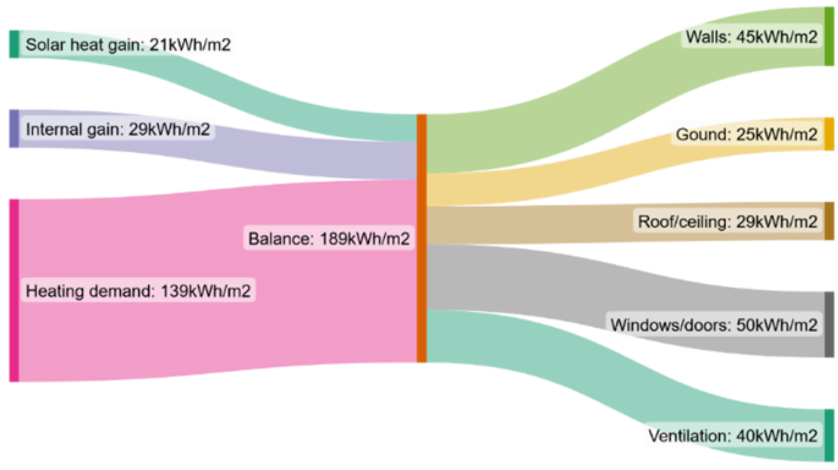

Figure 1. Heat balance for a typical multi-apartment building before renovation.

- Adding insulation to uninsulated boundary structures, including:
  - Outer walls;
  - Roof/ceiling or attic constructions, including flat roofs;
  - Slab-on-ground floors or outer walls below ground level.
- Implementation of a mechanical ventilation system with heat recovery.
- Replacement / retrofitting the old and inefficient components within the technical systems.

By implementing these recommended actions, significant improvements can be achieved in terms of heat loss reduction and energy efficiency in non-renovated buildings.

Activity 3. Study of actions in heat systems

During our analysis of urban heating systems, we discovered that mixed heat systems, which incorporate both district heating (DH) and local heating, are also popular in small cities and suburban areas. Taking this into consideration, we expanded the application of our project's results to encompass retrofitting local heat systems as well.

In the case of pipeline networks, the primary source of heat loss is through the surface of the pipes. The hydraulic regimes of DH networks have a minimal impact on heat loss, allowing us to initially ignore this component (specifically, heat consumption/flow) for preliminary assessments.

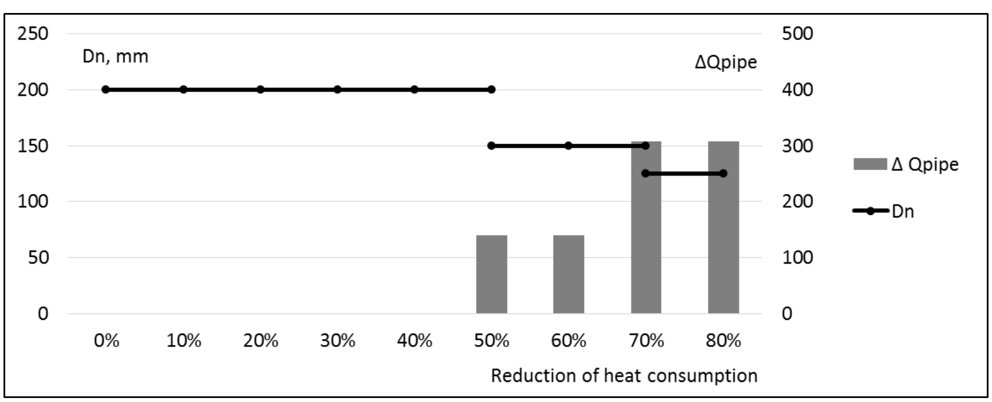

Figure 2. Potential impact of heat loss reduction ΔQ_{pipe} in DH network.

As achieving the set CO_2 reduction targets requires massive insulation of all buildings to nearly zero level, the heat flow will decrease significantly; it becomes possible to reduce the dimensions of the network pipes. By rebuilding the DH networks and reducing the diameters of the pipelines (Dn), the amount of heat loss within the network can be substantially reduced (ΔQ_{pipe} in Figure 2). This reduction in heat loss contributes to improved energy efficiency and cost savings in the heating system.

By reducing heat energy consumption and network losses, significant benefits are achieved, including reduced fuel consumption, primary energy savings, and decreased CO_2 emissions in the boiler house or local heat generator. It is important to note that the efficiency of heat generation in the heat source is primarily determined by the type and prices of the primary resource, and partial loading of the heat source has minimal impact on its efficiency.

To further enhance the benefits, the project also considers primary energy conversion to green resources and retrofitting of the heat source. The heat source module within our methodology calculates the total primary energy savings and reduction of CO_2 emissions achieved through these measures. This assessment provides a comprehensive overview of the environmental impact and sustainability gains resulting from the project's implementation.

Activity 4. Structuring normative acts

Given that heating contributes to a significant portion of primary resource consumption and GHG emissions (up to 30% in the EU), decarbonizing the building stock in a cost-effective manner is directly linked to various aspects of Union climate legislation.

Regulation 2021/1119 highlights the importance of fostering an inclusive and accessible approach to the multi-level governance process of the Green Deal, involving national, regional, and local entities, as well as social partners, academia, the business community, citizens, and civil society. The EU's model of multi-level governance is founded on the principle of subsidiarity. While Community normative acts traditionally focus on Union and Member State levels, there are overarching principles that can be applied to other levels of governance, including LGs. However, the specific implementation of the European Charter of Local Self-Government principles within the EU regulatory environment may vary due to national specificities and traditions.

Regulation 2018/1999 requires Member State governments to establish integrated National Energy and Climate Plans, as outlined in the respective regulations of each Member State (see Regulation of the Cabinet of Ministers No 46/2020). This process necessitates consultations and engagement with local and regional authorities. Active dialogues with "local authorities, civil society organizations, business community, investors, and other relevant stakeholders, as well as the general public" are prescribed. The regulation provides detailed provisions for regular progress reporting, while mechanisms for achieving "higher goals" have been left to the discretion of the Member States, aligning with the principle of subsidiarity.

Directive 2018/844 on the energy performance of buildings lays out strategic principles that require shared competence between state administrations and municipalities, along with the motivated involvement of building owners, addressing aspects such as energy efficiency, renewable energy integration, and the implementation of sustainable practices. To ensure effective and comprehensive building decarbonization efforts, several key factors should be considered:

- Integrated District Approach: Emphasizing an integrated district approach allows for the holistic renovation of multiple buildings within a spatial context, rather than focusing solely on individual structures. This approach enables synergistic effects and optimal energy performance improvements at the district level.
- Energy Performance Certificates: It is crucial to achieve overall coverage of the building stock through energy performance certificates, as mandated by the Law on the Energy Performance of Buildings. These certificates provide qualitative data essential for evaluating energy efficiency. To ensure accuracy and consistency, it is important to define and implement all necessary parameters for calculations, both for certification purposes and for meeting minimum energy performance requirements.

- Access to Financial Mechanisms: Facilitating access to suitable financial mechanisms for investors and the private sector is essential. Both the EU and national Recovery and Resilience Plans support investments in large-scale renovation projects targeting residential buildings, public buildings, and businesses. Complementary regulations, such as those outlined in the relevant Cabinet of Ministers' documents (e.g., No. 103/2021, 150/2022, 28/2023), provide additional guidance and support for financing sustainable renovation initiatives.

It is important to note that local and regional authorities play a crucial role in the consultation and cooperation processes. Given their significant intermediate role, the participation of LGs in the decision-making process is not only reasonable but also necessary. Including LG in co-decision processes ensures a more balanced approach, as decisions made solely by the UN and EU may not fully address the imperative of leaving no one behind.

By considering these factors and promoting inclusive collaboration among various stakeholders, sustainable building decarbonization efforts can be enhanced, fostering a more equitable and environmentally friendly future.

Activity 5. Developing informative base for the IS

To execute the project effectively, two implementation algorithms and their corresponding action lines were thoroughly analyzed.

Algorithm 1 involves calculating the heat consumption savings (ΔQ) by considering the current heat demand in buildings, losses in heat transmission pipes, and heat production plants/equipment (Q_C), as well as the same factors after renovation (Q_R). To minimize the number of indicators used, previous experience with obtaining key performance indicators (KPIs) and their objective mathematical weighting through regression analysis algorithms was generalized and applied. Mathematical expressions were derived to quantify the impact of each selected KPI. Insignificant indicators in the heat generation and transmission processes were identified. However, the calculations of the heat balance of buildings did not yield significant benefits due to the lack of interrelationships and mutual dependencies among the KPIs. Furthermore, uncertainties remain in calculating available internal and solar heat gains in buildings.

Algorithm 2 involves directly calculating the heat consumption savings (ΔQ). In this case, only aspects that are affected by the renovation process are included in the calculations. Aspects that remain unaffected by the recovery actions can be ignored, such as the orientation of buildings (and corresponding solar heat gains), functionality (and internal heat gains), network configuration and its temperature regime, and permanent costs of heat production. This algorithm effectively excludes uncertain aspects from the calculations and significantly reduces the number of KPIs, thereby enhancing the accuracy and simplicity of the calculations.

Based on the analysis, Algorithm 2 was selected, and direct ΔQ calculation was performed to develop a functional model of the urban heating system. The data structure in the information base and tiered tries were created in accordance with Algorithm 2. By utilizing this algorithm and developing a functional model, the project aims to improve the accuracy, simplicity, and efficiency of the calculations involved in assessing heat consumption savings and optimizing the urban heating system.

Activity 6. Creating entities in tired trees.

Given the hierarchical nature of data on heating system projects, components, and elements, a tree data structure is the most suitable algorithm for processing and organizing this information. It allows for the creation of hierarchies with varying leve ls of depth and complexity. In the case of the urban heating system model, the tree's root represents the system itself, while each node represents an entity, such as a project, component, or element (Figure 3). The edges connecting the nodes represent the causal relationships or impacts between these entities. Properties and attributes can be associated with both nodes and edges, serving as storage for information about the entities and their causal connections.

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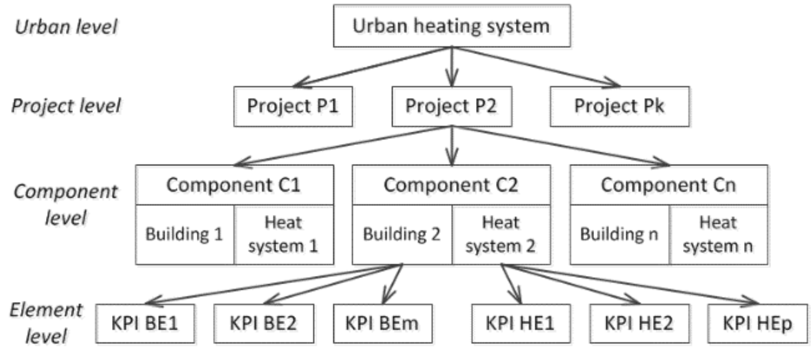

Fig. 3. Data model of urban heating system.

In the context of the total recovery/retrofitting of an urban heating system, this process can be represented as a 4-level structure, aligning with a corresponding 4-level tiered tree data model:

- At the urban level, the focus is on translating the multi-level political, economic, and financial actions outlined in Table 1 into specific renovation/retrofitting projects. A dynamic functional model of the city's heating system is created to initially assess the overall impact of these projects. By combining the output data from all projects, the total savings in heat and primary energy consumption, reduction of CO_2 emissions, necessary investments, and cost changes can be determined.
- At the project level, multiple implementation versions of specific projects (P_1, ..., P_k) are developed by considering the benefits and costs of renovating individual project components (C_1, ..., C_n). Each version represents a potential solution for reducing heat consumption, and the attributes associated with each option define the drivers and benefits of that particular version. A comparative analysis of these versions helps in selecting the most advantageous option based on specific funding and regulatory requirements. This level also contains important textual and spatial data related to project components.
- At the component level, the focus is on calculating and analyzing the potential benefits and costs associated with renovating or retrofitting individual components within different project implementation versions. For each component (such as a building or a specific part of the district heating system), the achievable heat consumption savings (ΔQ) in various project versions are determined by modeling the impact of key indicators (KPI BE_m for building elements and KPI HE_p for heat system elements) on the overall heat balance of the component.
- The element level (see also Figure 4) involves entering and processing essential thermal, structural, and financial data related to the specific elements (e.g., walls, windows, ventilation, pipes, etc.) of the project components. Manipulating the values of key indicators associated with these elements helps create different versions of the renovation/retrofitting project, enabling analysis and comparison to determine the most effective approaches.

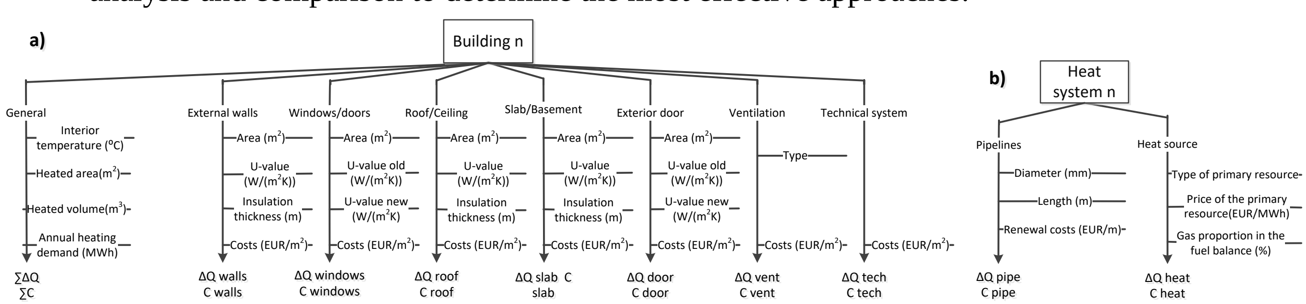

Fig. 4. Detailed element level of the data model; building (3a) and heat system (3b) branches.

By structuring the analysis at these four levels, the project aims to provide a comprehensive understanding of the renovation/retrofitting process, enabling informed decision-making and optimized outcomes.

Activity 7. Gathering data on buildings

In order to ensure the accuracy and validity of the methodology and tool we are developing, it is crucial to have access to reliable and representative data sets that reflect the heat balances of real buildings. These data sets should encompass a wide range of building types, including residential and non-residential buildings in both public and private ownership.

To fulfill this requirement, we made a formal request to the State Construction Control Bureau, seeking permission to access anonymized data from the Register of Building Energy Performance Certificates. These certificates are meticulously prepared by qualified professionals and provide comprehensive information on the energy performance of buildings. Our request has been granted, allowing us to obtain the anonymized data from the certificates issued in April 2022. These data sets have been carefully selected to meet the criteria of representing real buildings and covering various building types and ownership categories.

With the acquired data sets, we conducted extensive test calculations to evaluate the performance and accuracy of our methodology and tool. The results of these calculations exhibited a high degree of conformity and alignment with the actual heat balances of the buildings in the vast majority of cases. The utilization of data derived from energy performance certificates, developed by industry professionals, reinforces the reliability and robustness of our methodology and tool. This valuable resource enables us to apply our methodology and tool effectively in real-world scenarios, supporting decision-making processes for building renovation and retrofitting projects with increased confidence and precision.

Activity 8. Gathering data on district heating

Access to sufficiently complete, detailed, and comparable data regarding boiler houses, cogeneration plants, and DH systems, as well as their operation, is currently limited. However, to gather the necessary data for the quantitative part of the entities in the tired trees related to the heat system, we have conducted an extensive data collection effort utilizing multiple sources.

The data compilation process involved gathering information from various public sources, including annual reports of companies, reports from studies initiated by state governance institutions, decisions by the Regulator regarding tariff approval, public information on significant tariff components, and the Regulator's Register of district heat producers. Additionally, data on fuel consumption by energy producers was obtained from the Latvian Environment, Geology, and Meteorology Centre database (National statistical reports "2-Air").

In total, data from 97 companies were collected, including 57 DH companies and 40 independent heat producers. These data sets were carefully analyzed and incorporated into our analysis, ensuring that the information obtained from public sources was reliable and relevant.

Although the process of gathering data from multiple sources posed challenges, we have made diligent efforts to ensure the accuracy and integrity of the collected information. By utilizing this diverse set of data, we have been able to conduct a comprehensive analysis of the heat system, enabling us to develop a robust and informed methodology and tool for further evaluation and decision-making processes.

Activity 9. Gathering construction data

The construction cost data related to the calculations of investments for renovation and retrofit projects and the benefits derived from them should be considered indicative. This is because construction costs exhibit high variability both in terms of geographical location and over time. For instance, in January 2023, they were 34% higher compared to January 2021. An estimate, territorially averaged data for March 2023 has been provided by *Tames.lv*, a specialized firm in construction estimate calculations.

Activity 13. Creating ontologies

To achieve the main objective of identifying heat consumption savings in different renovation/retrofitting variants for each component within the overall system, an ontology concept was created for the categories used in the system. During the project development, two potential ontology structures correponding to algorithms in Activity 5 description, along with hierarchies of management entity trees and relevant action lines, were created and thoroughly analyzed. One of the key considerations was to ensure compliance with the project's requirement of using a limited number of indicators.

The ontology concept, along with separate hierarchies of management entity trees, was specifically designed for the direct calculation of ΔQ (the difference in heat consumption before and after renovation).

Activity 14. Software design.

The IS software consists of two main components: the database and the user interface.

In order to process the tired trees effectively, a graph database was selected as the ideal platform. Graphs provide a way to model data that closely resembles its real-world representation. This simplifies the operations for IS users who may not possess in-depth knowledge of thermal physics, economics, construction, or IT. Additionally, utilizing a graph database can enhance users' understanding of heat flows and facilitate the identification of areas that require improvement or renovation.

For data storage, processing, and management (database DB in fig. 5), a graph database management system (DBMS) called Neo4j was chosen. Neo4j is the most suitable DBMS for our needs, as the project data consists of multiple trees (graphs). Neo4j offers a declarative query language called Cypher, which enables reading and processing of graph data. Cypher is designed to be expressive, readable, and powerful enough to handle complex data relationships. Its syntax is similar to SQL, making it accessible for users familiar with SQL. Queries are written in plain text, and results are returned in a tabular format, similar to a relational database.

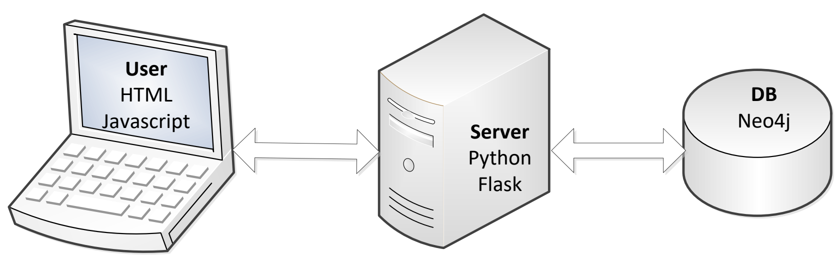

Fig. 5. Software architecture.

Neo4j incorporates a web interface called Neo4j Browser, which facilitates the visualization and exploration of stored graph data. This feature enables developers to gain a clear understanding of the data and develop queries tailored to their specific use cases.

To ensure accessibility to a wide range of users, a web service has been developed, allowing it to be utilized by anyone with internet access. The most up-to-date version of the IS software is readily available to users at any given time.

The web application has been developed using the Python framework Flask on the server side, while JavaScript is used for the web pages. This combination of technologies enables the creation of a dynamic and interactive user experience.

Activity 15. Software development

The development of the user interface software was guided by several key considerations:

1. The target user group consists of IT non-specialists who will use the IS software occasionally. Therefore, the user interface was designed to meet their needs by:
    - requiring only basic IT skills;
    - providing helpful feedback and error messages to guide users in their analysis and experimentation;
    - allowing easy uploading, processing, and visualization of data without requiring significant technical expertise;
    - offering simple and user-friendly tools for data entry, transformation, cleaning, and analysis, as well as intuitive visualization tools for presenting the analysis results.
2. Each user is intended to have their own IS, enabling them to:
    - experiment and test different scenarios without affecting the data or analysis of other users;
    - work independently and customize the IS according to their specific needs and preference;
    - maintain data privacy and security, as each user's data and analysis are kept separate from others.
3. Urban heating projects involve numerous components and elements, requiring the entry and processing of a large amount of data. To handle this effectively, the user interface was designed to:
    - provide user-friendly data entry forms that guide users through the process of inputting data;
    - be intuitive, with clear instructions and minimal technical jargon;
    - validate and check the entered data to ensure accuracy and completeness;
    - include simple and intuitive interfaces for editing data;
    - support the import and export of data in commonly used file formats.

Overall, the software was developed with a strong emphasis on usability and accessibility to ensure that a wide range of users can effectively achieve their goals. The aim is to provide a positive user experience and enable users to work efficiently and effectively with the software.

Activity 17. Creating IS test version

The development of the IS test version as a web-based system involved several steps:

1. Defining requirements: Operational studies were reviewed to identify the specific requirements for the IS. This included determining the ability to calculate building compliance with heating norms and assess the efficiency of the heat system.
2. Developing system architecture: Based on the defined requirements, a high-level system architecture was created. This involved outlining the different system components and defining their interactions.
3. Designing user interface: The user interface was designed to be intuitive and user-friendly. It includes clear navigation and appropriate visual elements to enhance usability.
4. Developing back-end functionality: This step involved creating the necessary database schema, data models, and algorithms to perform the required calculations and functions of the IS.
5. Building and trialing the IS test version: An agile iterative development process was followed to build the IS. The development started with basic functionality and progressively added more features and capabilities. The test version of the IS was thoroughly trialed to ensure that it met the defined requirements and functioned as intended.

By following these steps, the development of the IS test version as a web-based system was executed effectively, ensuring that it fulfilled the specified requirements and provided the desired functionality.

2. Influence

A methodology and a test version of an IS have been developed for the sustainable management of the urban heating system. The methodology and IS test version have the following characteristics:

- comprehensive coverage: they encompass the management of all components of the overall urban heating system;
- applicability: they are designed to meet the requirements of relevant projects and funding options available;
- project integration: they can combine multiple individual projects, facilitating a holistic approach;
- objective results: they provide objective and sufficiently accurate results for initial modeling and evaluation of project variants;
- accessibility: they do not require specific knowledge in thermal physics, economics, or construction, making them user-friendly;
- minimized indicators: they utilize a limited number of indicators to streamline the analysis process.

The developed management methodology and IS test version demonstrate the following outcomes:

- achievable savings: they show the potential heat consumption and primary energy savings.
- CO_2 emissions reduction: they illustrate the reduction in dominant CO2 emissions.
- financial implications: they indicate changes in heating tariffs and costs.
- investment requirements: they provide insights into the necessary investments.

The implementation of this research project is expected to contribute significantly to the advancement of management science and the measurement of climate policy implementation. It also brings new technological expertise and innovation in data processing methods.

In adherence to the principles of Open Access and Open Data, the initial theoretical findings of the study have been published or submitted to peer-reviewed scientific journals listed in the SCOPUS database.

1. G. Karnitis, J. Bicevskis, A. Virtmanis, E. Karnitis. Universal Methodology for Objective Determination of Key Performance Indicators of Socioeconomic Processes. In: *Digital Business and Intelligent Systems* (pp.47-62). DOI:10.1007/978-3-031-09850-5_4
2. G. Karnitis, J. Bicevskis, M. Pukis, U. Sarma, S. Gendelis, A. Eihmanis, A. Virtmanis, E. Karnitis. Methodology for Mathemetical Determining Key Performance Indicators of Socioeconomic Processes. *Baltic Journal of Modern Computing*, vol. 11 (2023), No.1, (pp.114-133). Doi.org/10.22364/bjmc.2023.11.1.07
3. M. Pūķis, J. Bičevskis, S. Gendelis, E. Karnītis, Ģ. Karnītis, A. Eihmanis, U. Sarma. Role of Local Governments for the Green Deal multilevel governance: energy context. *Energies* 2023, 16(12), 4759; doi.org/10.3390/en16124759. (SCOPUS Q1).

The methodical issues are partially presented also in scientific conferences:

1. G. Karnitis, J. Bicevskis, A. Virtmanis, E. Karnitis. Universal Methodology for Objective Determination of Key Performance Indicators of Socioeconomic Processes. 15th International Baltic Conference on Digital Business and Intelligent Systems, 4–6 July 2022, Riga, Latvia.
2. S. Gendelis, J. Bicevskis, A. Eihmanis, E. Karnitis, G. Karnitis, M. Pukis, U. Sarma. Methodology of sustainable management of the urban heating system in case of massive building renovation. XXIII International Multidisciplinary Scientific GeoConference Surveying, Geology and Mining, Ecology and Management – SGEM 2023, 1 - 10 July, 2023, Albena, Bulgaria. Accepted.

In the practical phase, a test version of the IS has been developed to evaluate the methodology aand key algorithms using real data from buildings, DH networks, and heat sources. In the second stage of the project, the methodological algorithms will undergo further refinement to enhance the quality of the expected results..

In general, in the first perion of the project implementation, the main focus was on finding optimal solutions in various segments of the methodology to be developed. e.g., opportunities to increase the role of the LGs, options for finding and using KPIs of the urban heating system, calculation algorithms of the heat savings ΔQ, software design strategies, selection of IT tools. Currently, information on the set project tasks and achievable goals is published in Latvian on the on the University of Latvia's portal (https://www.lu.lv/zinatne/programmas-un-projekti/nacionalas-programmas-un-projekti/flpp-2021-gada-konkurss/). Results of the project to provide valuable insights into the project and its outcomes to the public will be reflected in the second period.

3.Implementation

The progress of the project's implementation so far has confirmed that the choice of the interdisciplinary team of researchers from three faculties (the FBME, the FCS and the FPMO) was completely justified. The project is executed in accordance with the predetermined work plan and budget specified in the project application. It also confirms the good level of the project management and cooperation between project participants.

Only a few changes were encountered, which were anticipated as potential risks in the project application. These changes include:

1. Participant Dr. Akermanis expressed his intention to discontinue his involvement in the project team at the conclusion of the 8th month. As a result, his contract was terminated, and PhD applicant U. Sarma was added to the project team starting from the 9th month.
2. Undergraduate student L. Štekels also expressed a desire to cease participation in the project team at the end of the 16th month. Consequently, his contract was terminated.
3. Budget: due to the aptitude and interest of the involved master's student A. Eihmanis in software development, a portion of the budget allocated for programming was saved and will be rescheduled.

Nevertheless, these changes primarily affected the specified potential risk groups and did not present significant challenges to the overall project implementation.

In general, the level of risks for the complete execution of the project can currently be assessed as insignificant.