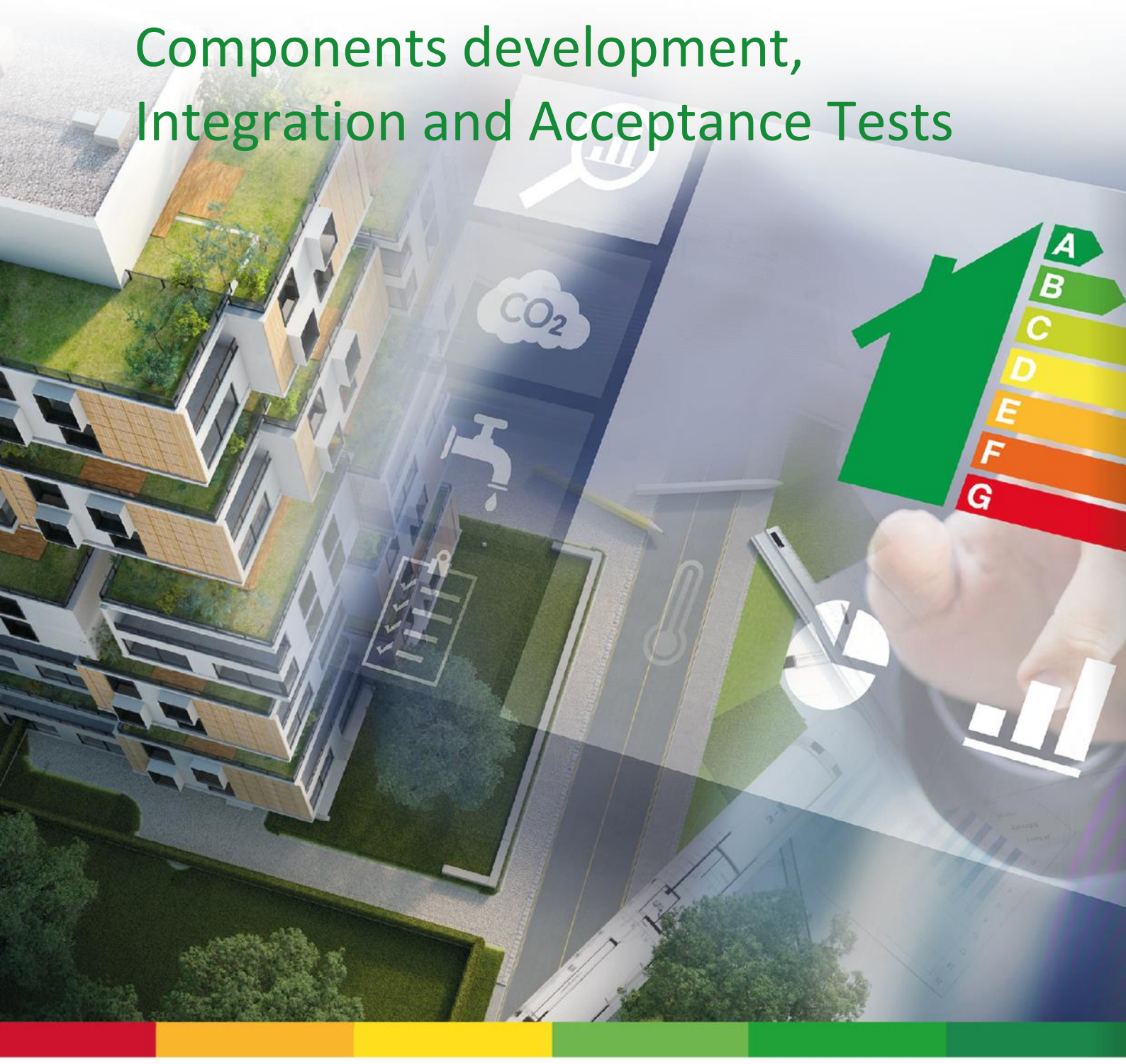
SmartLivingEPC Digital Platform: Components development, Integration and Acceptance Tests



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D5.1: SmartLivingEPC Digital Platform: Components development, Integration and Acceptance Tests

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Executive Summary

Work Package (WP) 5 aims to develop Added Value AI tools, alongside a comprehensive benchmarking and evaluation framework. Additionally, advanced user interfaces and visual analytics are being created to facilitate information visualization for end-users, thereby offering valuable insights into the performance of building units or complexes. All SLEPC components—including the Asset Rating engine and Operational Rating engine derived from WP2 and WP3, respectively, as well as the SLEPC Digital Twin, Common Information Exchange Model, and other elements from WP4—will be integrated into a unified operational framework within this WP.

Deliverable (D) 5.1 is the first deliverable of WP5 and includes the initial outcomes of all individual tasks within WP5. Specifically, it presents the functional description of the Added Value AI tools and the Nudge-ready Performance Benchmarking and Evaluation tool, along with the development plan. It also demonstrates the user interfaces of the SLEPC Web Platform, such as the welcome page, the main dashboard, the user profile pages, the BIM management page, the building complex management page, the device management page, and the issue reporting page. Furthermore, the user interfaces of developed and integrated components, such as the Asset Rating engine (including energy and non-energy indicators tabs), the Operational Rating engine and individual pages for the included indicators, are delivered. Finally, the integration plan for the components developed outside of the SLEPC Web Platform is described and the user acceptance tests, designed to ensure that the developed solution meets specific functionality, usability and compatibility requirements, are provided.

The present deliverable, together with the Web Platform prototype, offers insights into the finalized product. This product translates the research findings of the SLEPC project into practical applications, thus concluding the efforts under WP5.

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List of Acronyms and Abbreviations

Term	Description
ADASYN	Adaptive Synthetic Sampling
AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
ANN	Artificial Neural Network
APIs	Application Programming Interfaces
AUC	Area Under the Curve
BAS	Building Automation Systems
BIM	Building Information Modelling
CIEM	Common Information Exchange Model
CNNs	Convolutional Neural Networks
D	Deliverable
DBMS	Database Management System
DHW	Domestic Hot Water
DoA	Description of Action
DS	Demo Site
DTS	Dynamic Thermal Simulation
EE	Energy Efficiency
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certification
EU	European Union
EUI	Energy Use Intensity
HVAC	Heating Ventilation and Air Conditioning
IEQ	Indoor Environmental Quality
IoT	Internet of Things
KPI	Key Performance Indicator
LCA	Life Cycle Assessment

LCC	Lie Cycle Costing
LOF	Local Outlier Factor
ML	Machine Learning
MLPS	Multi-Layer Perceptrons
MOO	Multi-Objective Optimization
NPV	Net Present Value
NS	Net Savings
ODM	Object Document Mapper
ORM	Object–relational mapping
R	Correlation
RMSE	Root Mean Square Error
RNNs	Pecurrent Neural Networks
SLEPC	SLEPC
SMOTE	Synthetic Minority Over-sampling Technique
SRI	Smart Readiness indicator
SVM	Support Vector Machine
T	Task
UATs	User acceptance tests
UI	User Interface
WP	Work Package

1 Introduction

1.1 Scope and objectives of the deliverable

This deliverable is linked to WP5 and presents the initial version of the SmartLivingEPC (SLEPC) Web Platform. It integrates the services developed within the SLEPC project so far, offering user interfaces that display various functionalities. The document aims to provide insights into the chosen design approach for the system's architecture, outlining the functional and non-functional requirements considered, and the general development guidelines followed, in alignment with the SLEPC framework architecture defined in Task (T) 1.4 (Its outcomes are included in D1.3). Additionally, it details the provisioned Web Platform users, the corresponding User Stories, the platform's interfaces, including feature descriptions and results visualization. Finally, it delivers the integration plan of the SLEPC components and acceptance tests.

1.2 Structure of the deliverable

This report provides a description of all processes followed to develop the SLEPC Web Platform. To cover all these facets, this report is organized as follows:

- Chapter 2 provides a synoptic and coherent view of the system architecture as developed in WP1 and updated based on the WP2 and WP3, as well as the User Groups and User Stories as developed during WP5;
- Chapter 3 demonstrates the basic functionalities of some of the sub-components included in T5.1 Added Value AI Tools;
- Chapter 4 demonstrates the basic functionalities of the performance benchmarking and evaluation tool;
- Chapter 5 demonstrates the User Interfaces of the basic Web Platform functionalities and the visual representations of the SLEPC components;
- Chapter 6 highlights the SLEPC components integration plan and the corresponding acceptance tests.

1.3 Relation to Other Tasks and Deliverables

WP5, as one of the core development-related WPs in SLEPC, is closely related both with theoretical and technical work implemented in WP2, WP3 and WP4, accordingly. The modules' development is aligned with the architecture defined in terms of T1.4 and its updated version documented in D1.3. Both the development of the User Interfaces of calculation engines as well as their integration into the Web Platform is based on the work that has been performed in WP2 and WP3 and documented in all the related deliverables. More specifically, the updated methodologies of the individual component for asset and operational rating methodology are documented in D2.4 and D3.4 accordingly. The methodologies for building complex asset and operational rating are presented in D2.5 and D3.5 respectively. The final asset rating calculation methodology is presented in D2.6 and the final operational calculation methodology in D3.6, respectively. The retrieval of the relevant building information requires close collaboration with the work performed under T4.1 and documented in D4.4. Finally, in terms of this WP, the rest of the core development tasks of WP4 (T4.2, T4.3 and T4.4) and WP5 (T5.1, T5.2) guide the integration of other calculation functionalities into the Web Platform.

2 Background

2.1 System architecture

All elements of the SLEPC framework have initial definitions outlining their architecture and specifications. These details have been recorded in the updated version of D1.2 "SLEPC Pilot Analysis, Use Case Scenarios, and Framework Architecture" (delivered in M9), D1.3 (delivered in M21) served as a reference for future development stages of the project (i.e., activities of WP2, WP3, WP4 and WP5).

The documented requirements gathered from the pilot sites are merged with the user and market requirements extracted through D1.1 to establish the primary set of SLEPC Business Scenarios. These Business Scenarios are then classified into three key Business Groups, outlining processes for asset documentation, Energy Performance Certification (EPC) calculation, and the platform's advanced computation services, respectively. Additionally, the document outlines the platform's requirements necessary to define the range of included services. Two primary sets consisting of 43 functional and 13 non-functional requirements categorize the technical and user-related specifications essential for ensuring the delivery of a widely accepted solution. Based on all the aforementioned information, the SLEPC Conceptual Architecture Framework were designed composed four distinct layers (see Figure 1):

- The Data Collection Layer forms the foundation of SLEPC's conceptual architecture, acting as the main repository of information, which includes both static data and dynamic information. This layer contains documented building information from Building Information Exchange Model (BIM) files or other reports (e.g., Technical Audits) and includes the infrastructure for sensing and metering asset conditions via Internet of Things (IoT) devices. It also integrates all Application Programming Interfaces (APIs) used to gather data from the web.
- Following this is the Information Management Layer, which extracts information from the Data Collection Layer and formats it according to the platform's specifications. This layer has two key components: the Common Information Exchange Model (CIEM), which validates and stores various types of information from the Data Collection Layer to build the data model; and the SLEPC Digital Twin, which facilitates data correlation to model the asset's dynamic behavior, offering a virtual representation of the asset and enhancing the platform's capabilities.
- The Processing Layer houses the SLEPC's calculation core, responsible for assessing asset performance. This layer comprises components for calculating Asset and Operational Ratings. The Asset Rating Engine encompasses components for Energy and Non-Energy Resource Analysis, SRI calculation, Environmental Life-Cycle Assessment, and extraction of Asset Ratings at the Building Complex level. The Operational Rating Engine includes tools for Operational Level Energy Analysis, Financial and Indoor Environmental Quality (IEQ) indicators calculation, and Building Complex Assessment – Operational Rating. Both engines correlate results from their sub-components using a weighted approach to yield a unified rating for the building unit under study. In addition to the Calculation Engine, the Processing Layer encompasses the SLEPC Insights Suite, offering valuable insights for building owners to enhance performance and optimize energy usage. The Added Value Services group aims to provide stakeholders with a comprehensive asset representation through tools such as the Digital Building Logbook, Nudge-ready Performance Benchmarking & Evaluation, and Building Dynamic Behaviour Monitoring System. Moreover, the Added Value AI tools enhances the platform's intelligence by integrating six sub-modules/engines: Anomalies Detection on Assets Operation, Scenarios Simulation and Evaluation, Comfort Inference Engine, Disaggregation Engine, Activity Inference Engine, and Cost Estimation Engine. These Artificial Intelligence (AI) services play a critical role in augmenting the efficiency and effectiveness of the SLEPC system.
- The platform's results are represented in the User Interface (UI)/Demonstration Layer. The SLEPC Web platform serves as the primary interface for end-users and incorporates all necessary APIs to facilitate communication with third-party platforms and tools.

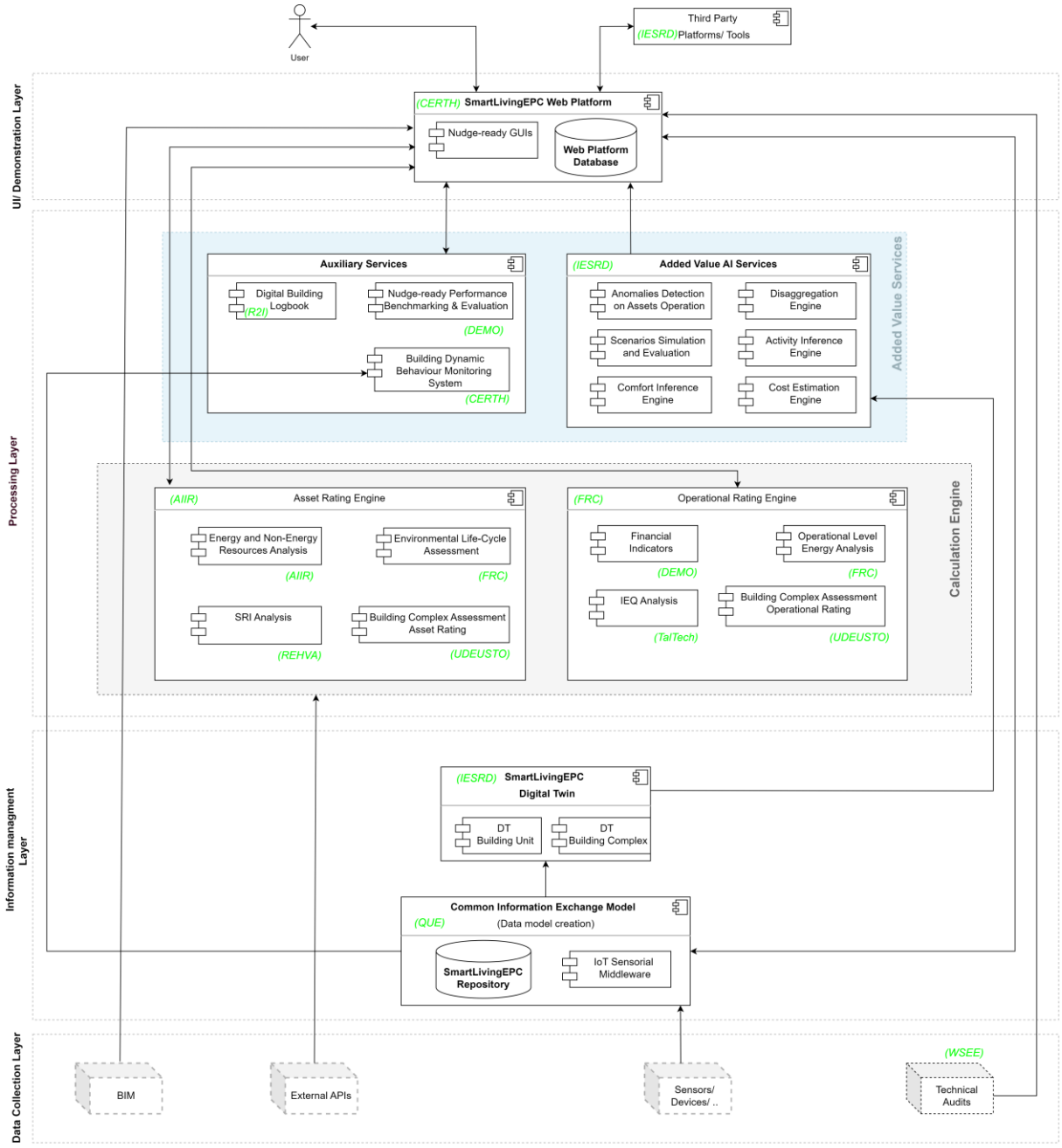

Figure 1: Layered conceptual architecture diagram

The platform's functionality was examined from four distinct viewpoints: Functional, Deployment, Information, and Dynamic views. The Functional View assessed the operational specifications of the major layers/components within the conceptual architecture framework individually. Each component is broken down into its sub-components, with an analysis of included functionalities and communication requirements. These requirements are then used to derive the platform's Information View, which documents all communication channels needing definition among the components. Lastly, the Dynamic View elaborates on how the platform's components collaborate to fulfil a wide range of seven Business Scenarios, further divided into 24 Technical Use Cases.

2.2 User groups

Understanding the user groups of SLEPC Web Platform is essential for ensuring that the design and functionalities meet the diverse needs of all users. This section of the report will identify and describe the different user groups that interact with the Web Platform. By analysing their unique characteristics, requirements and usage patterns, an optimal user experience for each group will be provided. This comprehensive overview (See Table 1) will highlight how the platform supports its users effectively, driving engagement and satisfaction across all stakeholders.

Table 1: Web Platform Users definition

User Type	Description
EPC Unit Assessor	This is the main user of the platform, eligible to perform all the available actions related to building performance assessment (edit information related to building units, edit the assessment parameters of the different provided services) and issue an EPC.
EPC Copmplex Assessor	This user is able to perform actions related to the neighbourhood perfomance assessment. They are able to register neighbourhoods (edit information related to building complexes, edit the assessment parameters of the different provided services) as well as calculate their KPIs.
Building Owner	This user is not able to edit the assessment parameters of the different provided services and is limited to viewing the calculated results. They can give access to the EPC Assessor to edit and issue an EPC.
Administrator	This user makes sure the platform works, checks errors, warnings, logs, resolves issues with user accounts etc. They have full access to all building performance data that have been uploaded to the Web Platform, as well as for user management purposes.
Authority	The Public Bodies/Registries may assign such a user. This user has a wider overview of the building assessment results and has the ability to execute extended functionalities of the Performance Benchmarking and evaluation tool, in order to gain insights into multiple building performance data. They can give access to an EPC Assessor to edit and issue an EPC for building complexes.

2.3 User Stories

Based on an agile software development approach, user stories are short, simple descriptions of a feature or functionality from the perspective of a user. They are used to capture requirements and help the development team understand the needs and expectations of the users. User stories are defined using epics, which are large work items broken down into a set of stories, and multiple epics comprise an initiative (See Figure 2).

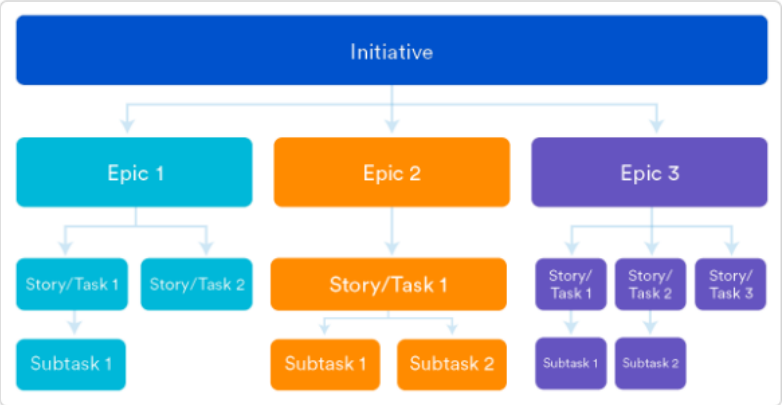

Figure 2: User stories definition diagram [1]

The definition of the User stories is a vital action in the development and refinement of the SLEPC Web Platform. They offer detailed insights into the needs, expectations, and interactions of various SLEPC users, as presented in Section 2.2, with the platform. By focusing on user stories, we can ensure that the platform's functionalities align closely with user requirements, ultimately enhancing usability and satisfaction.

This section presents the user stories that have guided the design and implementation of the SLEPC Web Platform. Each user story encapsulates specific user goals and scenarios, providing a narrative that helps in understanding the practical applications of the platform's features. The user stories serve as a reference for developers and stakeholders, ensuring that the platform remains user-centric throughout its development lifecycle.

The User Stories for SLEPC are documented in *ANNEX A: SLEPC User Stories*.

3 Added Value AI Tools

3.1 Introduction

This section is related to T5.1, which focuses on the development of AI-enhanced tools designed to analyse real-time data from buildings. The final tools will be providing insights into their behaviour and usage to promote energy efficiency.

They include a comfort inference engine to assess thermal comfort, an activity inference engine to monitor occupant activities, a disaggregation engine to estimate individual appliance energy consumption, an anomaly detection engine and a cost estimation engine. Additionally, a simulation tool for modelling building energy and usage patterns tools is included in the task, which is not a data driven engine, but a physics-based tool integrated in the Digital Twin.

This report covers the development, evaluation and testing results of the comfort inference and anomaly detection engines, with updates on other tools to follow on the next iteration as development progresses and pilots' data is stored in the CIEM, which will be further integrated with the AI tools. Table 2 below outlines the description of ell engines along with the user story.

Table 2: AI Engines General Description

TITLE	THERMAL COMFORT PREDICTOR
User Story	As a facility manager, I want to use an AI-powered tool to predict thermal comfort indoors, so that I can ensure a comfortable environment for building occupants.
Description	Comfort generator from measured data. This tool uses environmental data to predict and maintain optimal thermal comfort for indoor spaces.
Actors	Facility Manager, Building Occupants
Preconditions	Availability of sensors to measure environmental data, integration with HVAC systems.
TITLE	**ACTIVITY FORECASTER**
User Story	As a building manager, I would like to forecast the occupant activities/presence to improve building operations and optimize resource usage.
Description	Capable of determining the presence of the occupants at a specific time based on energy and non-energy source usage.
Actors	Building Manager
Preconditions	Access to data from energy and non-energy sources, user consent for data usage.
TITLE	**MAINTENANCE ANOMALIES DETECTOR**
User Story	As a maintenance engineer, I rely on the anomalies detection engine to proactively schedule maintenance and address potential issues before they lead to downtime.
Description	This engine identifies anomalies in energy consumption and activity patterns, allowing for proactive maintenance and issue resolution before significant downtime occurs.
Actors	Maintenance Engineer
Preconditions	Historical data on energy consumption and activity patterns, integration with maintenance systems.
TITLE	**DISAGGREGATION AND APPLIANCE ENERGY ESTIMATOR**
User Story	As a building occupant/home owner, I would like to use a service that allows me to schedule residential appliances for the following day to optimize cost and reduce spikes in demand.
Description	Responsible for estimating the energy consumption of individual appliances based on the overall consumption of the building in a low-cost and non-intrusive manner.
Actors	Building Occupant, Home Owner
Preconditions	Availability of appliance-level energy consumption data, integration with scheduling systems.
TITLE	**ENERGY COST ESTIMATION**

User Story	As a building occupant, I would like to understand/predict the energy/non-energy building asset consumption and estimate the cost for the next day.
Description	Able to perform rough cost estimations of the energy and non-energy building asset consumption, helping end-users better understand and perceive costs through a calculated channel in IES Live.
Actors	Building Occupant
Preconditions	Access to tariff information and measured consumption data, integration with cost estimation tools.

At this stage, to validate the models for the SLEPC project, data were requested individually from all pilots. This approach allows to accelerate the process and ensure the delivery of at least two fully operational engines. The following shows the main data request checklist for each of the engines to be developed and includes data points, the source, the data type and the granularity required.

SLE	T5.1 AI Added Value Services			
Objetive	Request data from pilots responsible (CERTH, TalTech and FRC)			
Engine	**Data Point**	**Source**	**Data type**	**Granularity**
Comfort Engine (Thermal/visual)	Indoor temperature	IoT Sensor	Timeseries (once a hour)	Hourly
	Exterior air temperature	Weather Service	Timeseries (once a hour)	Hourly
	Clothing levels	Survey	Table (for every year and month with a corresponding value)	Refer to example sheet
	Mathabolic rate	Survey	Table (for every year and month with a corresponding value)	Refer to example sheet
	Air velocity	IoT Sensor	Timeseries (once a hour)	Hourly
	Indoor humidity	IoT Sensor	Timeseries (once a hour)	Hourly
	Building climate region	Survey	One value	1
	HVAC system specs (natural/mech ventilation)	Survey	One value	1
	People presence (motion)	Survey/IoT	Timeseries (once a hour)	Hourly
	Thermal comfort votes	Survey	At least 3 times per day per occupied space, check Comfort Engine sheet for details	Refer to example sheet
	Luminance	IoT Sensor	Timeseries (once a hour)	Hourly
Activity assessment engine	Time of use survey: recorded activities	Survey	once a hour for a month for different people in the same building	Refer to example sheet
	People count (number of people in the room)	Survey	Timeseries	Refer to example sheet
	People presence (motion)	IoT Sensor	Timeseries	Flexible but at least 1 hour
	Main/aggregated meter data	IoT Sensor	Timeseries	Flexible but at least 1 hour
	Smart plugs / sub meters	IoT Sensor	Timeseries	Flexible but at least 1 hour
Disaggregation	Appliance level data	IoT Sensor	Timeseries	Flexible but at least 1 hour
	Brand and type of devices	Survey	One value (e.g. Samsung, LG etc along with its model)	1
	Main/aggregated meter data	IoT Sensor	Timeseries	Flexible but at least 1 hour
Anomaly detection engine	Indoor temperature	IoT Sensor	Timeseries	Flexible but at least 1 hour
	Humidity	IoT Sensor	Timeseries	Flexible but at least 1 hour
	CO2 concentration	IoT Sensor	Timeseries	Flexible but at least 1 hour
	Electricity consumption	IoT Sensor	Timeseries	Flexible but at least 1 hour
	Gas consumption	IoT Sensor	Timeseries	Flexible but at least 1 hour
	People count (number of people in the room)	IoT Sensor	Timeseries	Flexible but at least 1 hour
	People presence (motion)	IoT Sensor	Timeseries	Flexible but at least 1 hour

Figure 3: AI Engines Data Request Checklist

3.2 Case Study: Smart House

The initial evaluation of the AI engines utilises the CERTH Smart House pilot as a practical case study. This preliminary method serves as a foundation until pilot data is collected and structured within the CIEM for Smart Living EPCs, which will ensure a standardized approach to data handling and analysis.

The CERTH/ITI Smart House[1] in Thessaloniki, Greece, serves as a pioneering example of integrating advanced construction materials and intelligent ICT solutions to achieve a near-Zero Energy building. It is located in Thessaloniki, Greece, was constructed in 2016 and features a living area of 316 m². This innovative project is Greece's first near-Zero Energy building, combining advanced designed for testing, validating, and evaluating new technologies.

The building's envelope includes 16 cm of rockwool insulation, providing thermal, water, and sound insulation, as well as soundproofing. The window frames utilize the latest aluminium-based technologies, featuring triple glass in the central area (U = 0.6 W/m²) and double glass in the supporting areas (U = 1.1 W/m²).

[1] SmartHome / ITI

Regarding systems, includes a total installed load of approximately 30 kW for the main house and 20 kW for supported areas. The outdoor perimeter smart lighting load is 450 W. The house is also equipped with PV Panels. In terms of performance, the Smart House has an EPC Class of A+ and Smart Readiness Indicator (SRI) score of 56%. Building Information Modelling (BIM) is also available, further enhancing its status as a cutting-edge, sustainable building.

The provided data from the CERTH Smart House pilot to test the developed AI engines included consumption data for the entire building and the fridge, a model image of the fridge, and potentially additional data or documentation for the living room and office on the first floor, as well as weather data.

3.3 Thermal Comfort Engine

3.3.1 Background

3.3.1.1 Objectives and User Story

Thermal sensation is a subjective measure of an individual's perception of their thermal environment. It is influenced by a variety of factors, including air temperature, humidity, air velocity, and clothing insulation. Predicting thermal sensation can be challenging due to the complex interactions between these factors and individual differences in thermal perception. The goal of this research is to develop an AI model that can accurately predict thermal sensation using objective indoor climatic data.

Thermal sensation refers to a person's subjective perception of their thermal environment. It is typically measured on a 7-point scale ranging from cold (-3) to hot (+3), with 0 being neutral.

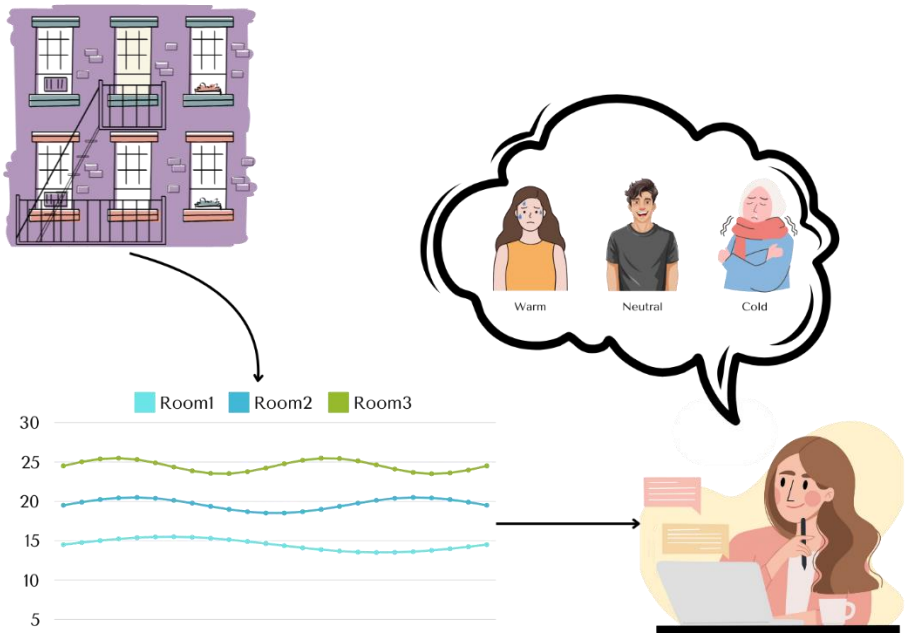

Figure 4: Thermal Comfort Engine's user story

The primary objectives for the comfort engine are:

1. To collect and analyze a large dataset of objective indoor climatic observations and subjective thermal sensation evaluations.
2. To identify the most important factors that influence thermal sensation and their interactions.
3. To develop and train an AI model that can accurately predict thermal sensation using objective indoor climatic data.
4. To evaluate the performance of the AI model in predicting thermal sensation and compare it to existing models.

The proposed research will provide a tool for predicting thermal comfort in indoor environments. The AI model developed in this research has the potential to improve indoor thermal comfort and reduce energy consumption by providing accurate predictions of thermal sensation that can be used to optimise Heating Ventilation and Air Conditioning (HVAC) systems.

The end-goal is to provide users with an API in order to get predictions without practicing any complex code development.

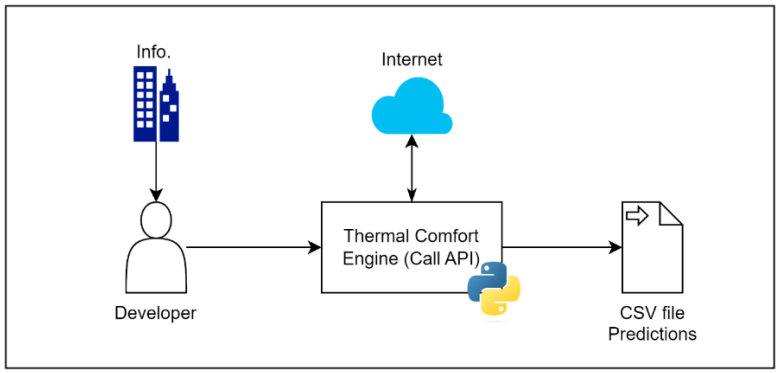

Figure 5: API for Thermal Comfort Engine

3.3.1.2 Model overview and Architecture

Model overview is depicted in the figure below, which shows sequential steps required to build the Machine Learning (ML) model. It includes 1-Pre-processing step, 2-Feature Selection, 3-Outlier Detection, and 4-ML pipelines. Each step is described in the following sections.

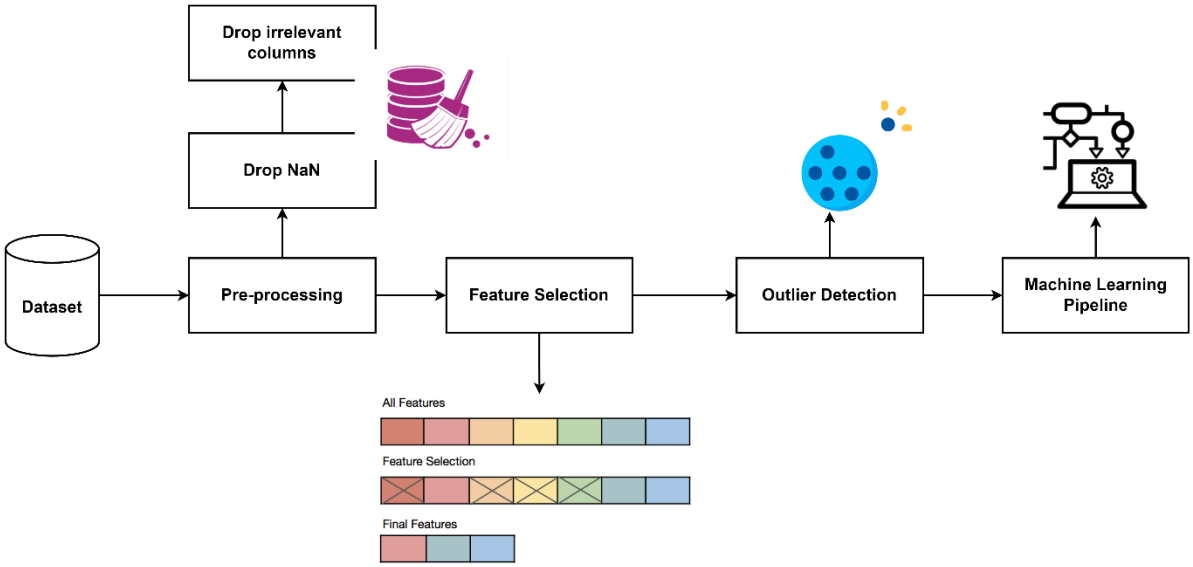

Figure 6: Thermal Engine Model

3.3.2 Methodology

The methodology detailed below provides a comprehensive framework for developing the SLEPC predictive model for thermal comfort using ML techniques. Beginning with the selection and preparation of datasets, supplemented by pilot data from the CERTH Smart House, creates the basis for subsequent pre-processing and data analysis stages. These phases involve critical tasks such as handling missing values, encoding categorical data, selecting relevant features, and detecting outliers, all aimed at ensuring data quality and suitability for ML applications.

Furthermore, the methodology includes the construction of a robust ML pipeline with techniques for handling imbalanced datasets and evaluating model performance. Finally, it outlines the development of an API for deploying predictive models, enhancing accessibility and usability.

DATASET FOR TRAINING AND TEST PURPOSES

a) Training & Testing

Data for training purposes has been taken from ASHRAE Global Thermal Comfort Database II[2]:

- It is an open-source research database that was launched in 2014 by the University of California at Berkeley's Center for the Built Environment and The University of Sydney's IEQ Laboratory. The database contains approximately 81,846 complete sets of objective indoor climatic observations with accompanying subjective evaluations by building occupants.
- It intends to support diverse inquiries about thermal comfort in field settings. The data in the database comes from field studies conducted between 1995 and 2015 from around the world. The database includes both instrumental (indoor climatic) and subjective (questionnaire) data that were recorded in the same space at the same time. This data can be used to explore the relationship between objective indoor climatic conditions and subjective thermal comfort evaluations.

[2] ASHRAE Global Thermal Comfort Database II (kaggle.com)

b) Pilot Data

Provided data from the CERTH Smart House pilot were described in section 3.2:

- Consumption data for the entire building and the fridge, a model image of the fridge, and potentially additional data or documentation for the living room and office on the first floor, as well as weather data.

PRE-PROCESSING & DATA ANALYSIS

a) Pre-processing:

- Before delving into the development of a machine learning (ML) model, it is imperative to undertake several pre-processing tasks to ensure the data is properly prepared and to avoid potential errors or misunderstandings in the model. A high-level representation of this phase is illustrated in the figure below.
- Initially, incomplete columns—specifically those with a significant number of missing (NaN) values—are removed. Following this, only the columns containing valuable data are retained. For columns with a substantial amount of data, it is necessary to filter them by eliminating rows that contain NaN values. By the conclusion of the pre-processing phase, we obtain a robust dataset that can be utilized to create effective ML pipelines.

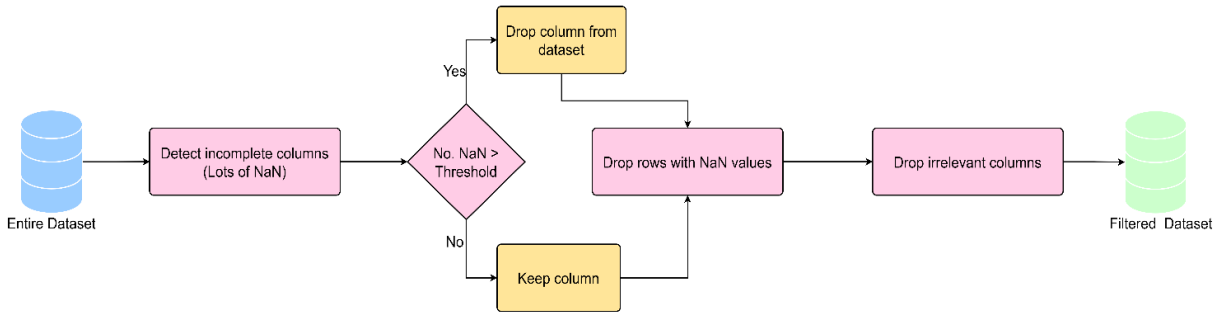

Figure 7: Data Analysis process

b) Encoding Categorical Data:

- Certain columns in the dataset, specifically training one, contain categorical information, where the values are represented as characters rather than numerical values. For instance, there may be a column labelled "season" with values such as summer, winter, etc. However, machine learning models are unable to process character data and require numerical values for effective data processing. Consequently, it is essential to convert these categorical columns into numerical values through a process known as encoding. Two commonly employed approaches for encoding categorical data are one-hot encoding and label encoding.
- Label encoding is appropriate when there is a sequence or order within the categorical data, such as seasons represented by numbers from 1 to 4. In this case, label encoding assigns a numerical value to each category while preserving the inherent order.
- Conversely, when the categorical data does not follow a specific sequence or pattern, such as country names, one-hot encoding is preferred. One-hot encoding creates new columns based on the unique

categories in the original column. For example, if there is a column representing countries, one-hot encoding would generate individual columns for each country. In these columns, a value of 1 indicates that the row corresponds to that particular country, while a value of 0 indicates otherwise.

- By applying appropriate encoding techniques, we enable machine learning models to effectively interpret and utilize the categorical information in the dataset.

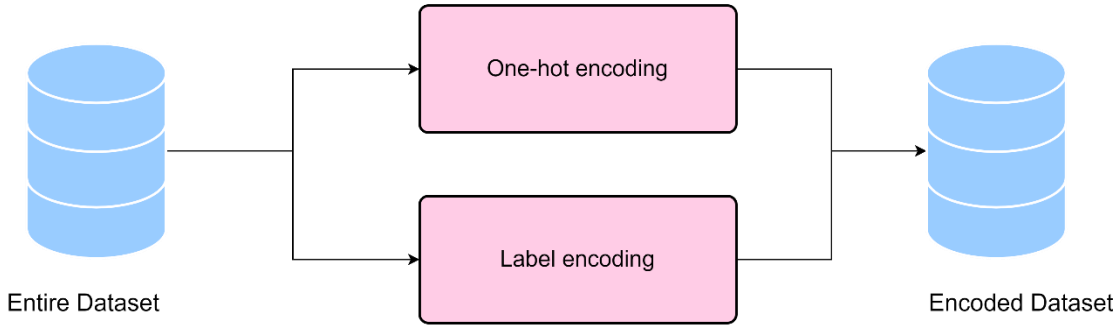

Figure 8: Encoding techniques

c) Feature Selection:

Feature engineering is an essential step in machine learning where we can transform and create new features from existing ones to enhance the predictive power of our models or select the most relevant ones from the available set of features (columns). It involves extracting meaningful information, identifying relevant patterns, and representing the data in a way that is more suitable for the learning algorithm. The goal is to improve model performance, increase accuracy, and capture important relationships within the data.

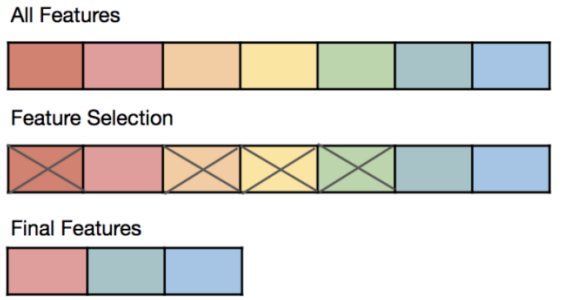

Figure 9: Feature selection

There are several reasons why we perform feature engineering. Firstly, it helps in removing irrelevant or redundant features that may add noise or confusion to the model. By selecting the most informative and impactful features, we can reduce the dimensionality of the dataset and improve computational efficiency. Additionally, feature engineering allows us to capture complex relationships and interactions between variables, enabling the model to learn more effectively.

Two common approaches for feature engineering are mutual information and correlation analysis. Mutual information measures the statistical dependence between two variables and provides insights into the amount of information that can be gained about one variable by knowing the other. It helps in identifying features that have a high degree of mutual information with the target variable, indicating their relevance in predicting the outcome.

Correlation analysis, on the other hand, measures the strength and direction of the linear relationship between two variables. It helps in identifying features that are highly correlated with the target variable or with each other. High correlation suggests a strong relationship, and such features can provide valuable information to the model.

Using these approaches, we carefully evaluated the available columns and selected the best features for our models. Our feature engineering process aimed to enhance model performance, improve accuracy, and enable the model to learn meaningful relationships without introducing additional features.

d) Outlier Detection:

Outlier detection is a crucial step in data analysis and machine learning, aimed at identifying and handling data points that deviate significantly from the normal behaviour or distribution of the majority of the data. Outliers can adversely impact the performance and accuracy of machine learning models by introducing noise, bias, or skewing the learned patterns. Therefore, it is important to detect and appropriately address outliers in order to build robust and reliable models.

In the case of a multi-class problem, it becomes even more essential to perform outlier detection on a per-class basis. This is because outliers may have different distributions or behaviours across different classes. By conducting class-specific outlier detection, we can capture class-specific anomalies or patterns that could be missed by treating the problem as a single entity.

To perform outlier detection, we utilised several commonly used approaches. These approaches include:

- **Local Outlier Factor (LOF)**: LOF measures the local density deviation of a data point compared to its neighbours, identifying points with significantly lower densities as potential outliers.
- **Isolation Forest:** Isolation Forest works by isolating outliers into individual trees, making it easier to detect them as they require fewer steps to isolate.
- **Robust Covariance:** Robust Covariance estimates the parameters of multivariate Gaussian distributions, identifying outliers as data points that do not conform to the estimated distribution.
- **One-Class Support Vector Machine (SVM):** One-Class SVM is a support vector machine algorithm that aims to separate the normal data points from outliers by creating a hyperplane that encloses the normal observations.

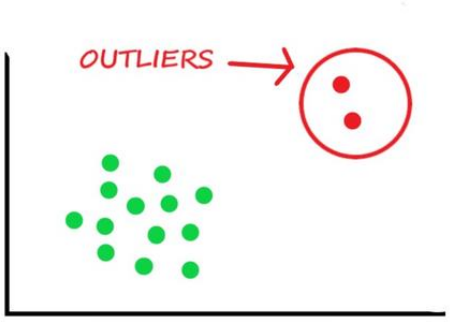

Figure 10: Outlier Detection

By utilising these outlier detection methods, we were able to identify and handle outliers specific to each class in our multi-class problem. This approach allowed us to ensure the integrity and reliability of our data, enabling the machine learning models to learn from clean and representative patterns.

e) Machine Learning Pipeline:

The final and crucial step of this project is to construct the machine learning pipeline, exploring various approaches to achieve high accuracy results. Below shows an overview of developed ML pipeline in this project.

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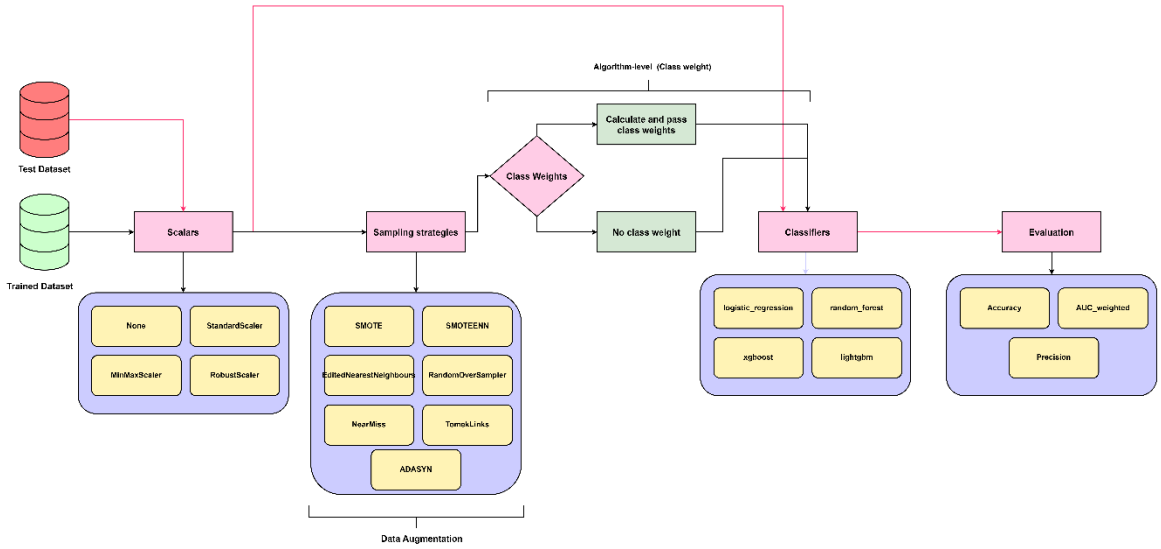


Figure 11: SLEPC Machine Learning pipeline

To build our models, we divided the dataset into training and testing sets. The training set is used to train the models, while the testing set is used to evaluate their performance on unseen data.

Scalars:

To improve the performance of our models, we applied different scalar techniques. These techniques include:

- None: No scalar applied
- MinMaxScaler: Scales the features to a specific range
- StandardScaler: Standardizes the features by removing the mean and scaling to unit variance
- RobustScaler: Scales the features using statistics that are robust to outliers

Imbalanced Dataset:

Since we have an imbalanced dataset, we employed various sampling strategies to address this issue.

An imbalanced dataset refers to a dataset where the distribution of classes or labels is heavily skewed, meaning that one or more classes are significantly underrepresented compared to others. In other words, there is an unequal distribution of data points across different classes. This imbalance can pose challenges in machine learning tasks as models may struggle to learn patterns from minority classes or may prioritize majority classes, leading to biased or inaccurate predictions. Handling imbalanced datasets often requires employing specific techniques such as sampling strategies, class weighting, or using evaluation metrics that account for class imbalance.

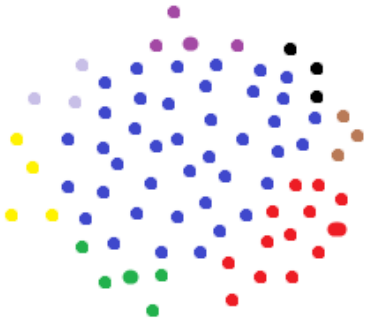


Figure 12: Multiclass Imbalance

The strategies used are as follows:

- SMOTE: Synthetic Minority Over-sampling Technique
- SMOTEENN: Combination of SMOTE and Edited Nearest Neighbors
- RandomOverSampler: Randomly replicates minority class samples
- NearMiss: Selects samples from the majority class to improve class balance
- TomekLinks: Removes samples from both majority and minority classes that form Tomek links
- ADASYN: Adaptive Synthetic Sampling

Class Weights:

To handle class imbalance, we also considered using class weights during model training. Class weights assign higher weights to minority classes, allowing the model to give them more importance.

Evaluation:

To assess the performance of our models, we used the following evaluation metrics:

- Accuracy: Measures the overall correctness of the model's predictions
- Precision: Measures the model's ability to correctly identify positive instances
- Area Under the Curve (AUC) weighted: Calculates the area under the receiver operating characteristic curve, considering class imbalance

By implementing these components in our machine learning pipeline, we aimed to achieve accurate and reliable results for our project.

f) API

The main features of the Predictive thermal comfort API are:

- The API accepts multipart/form-data input payload.
- The API accepts an input .csv file through multipart/form-data feature.
- The API response provides a .zip file which contains comfort results and a log file.
- The API when fails provides a log file as response which contains the error.
- It includes Swagger documentation for testing.
- It facilitates error and schema handling.
- It provides meaningful errors to the front-end (if any).

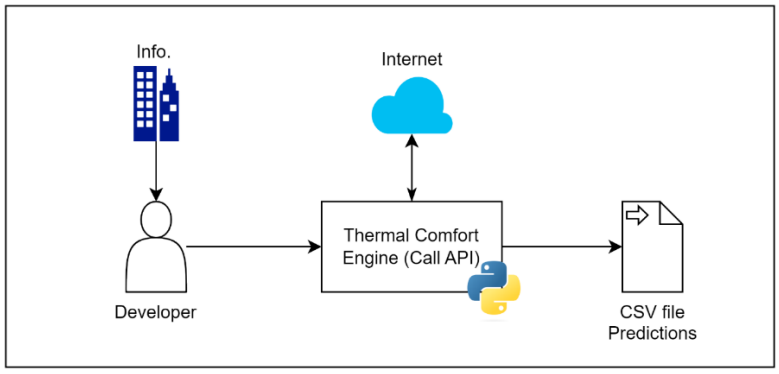


Figure 13: API Workflow

Step by step instructions for testing the API:

- Link for swagger documentation: https://pi-thermal-comfort-api.azurewebsites.net/swagger
- Please make sure the site is secure and there is a lock symbol in the address bar if not prefix https:// before the link
- In the Servers dropdown, select https://pi-thermal-comfort-api.azurewebsites.net/ as the server
- Click on the try it out button
- Select a file to upload
- Fill in the values for other fields
- Please press execute in order to run the API
- The response of the API provides a link which can be then copied in the browser in order to obtain results.

3.3.3 Testing and Results

In this section, the results from the pilot study are discussed. The figure below presents a histogram of indoor air temperature. As observed, the majority of the data is concentrated between 20 and 30 degrees Celsius.

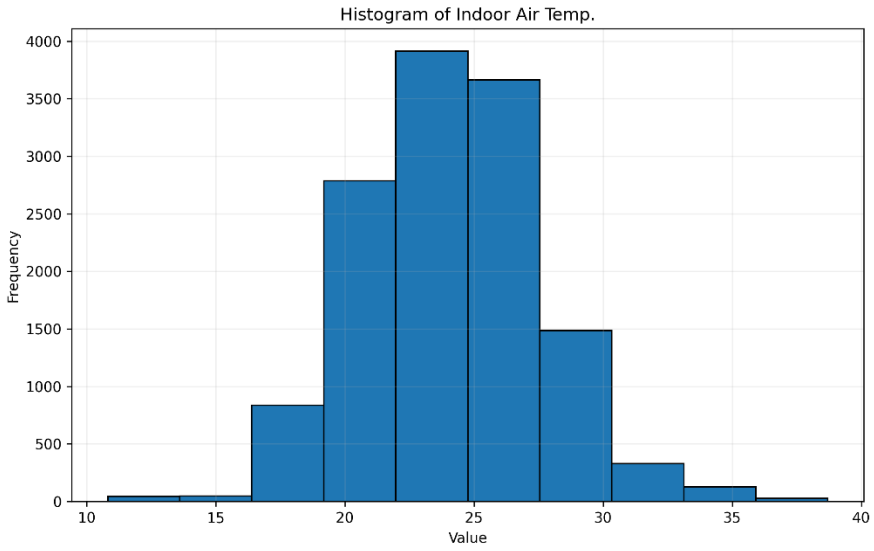


Figure 14: Histogram of indoor air temperature

Figure below shows the ML engine prediction, which shows the majority of data points being considered as comfortable.

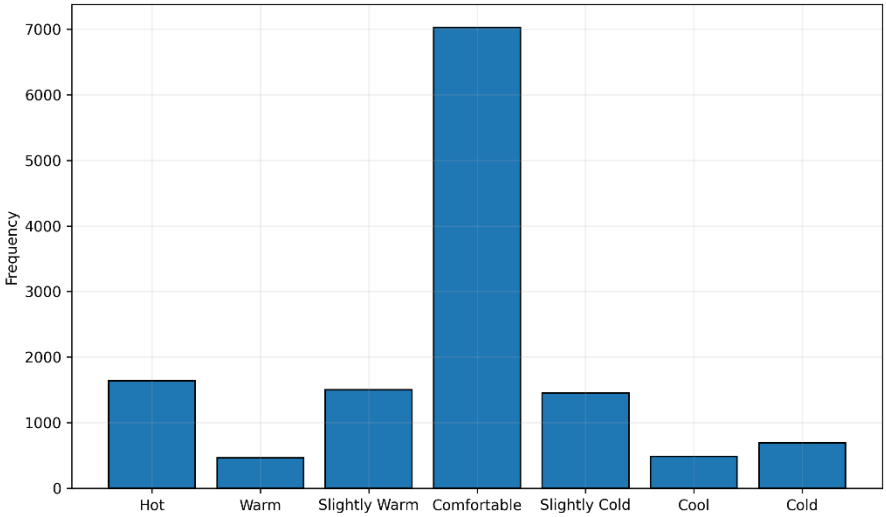


Figure 15: ML Model prediction

Table below is also summarising the results from ML predictions.

Table 3: ML prediction results

Category	Frequency	Percentage
Hot	1641	12.4%
Warm	462	3.5%
Slightly Warm	1501	11.3%
Comfortable	7026	53%
Slightly Cold	1453	11%
Cool	483	3.6%
Cold	691	5.2%

Figure below illustrates the relationship between indoor air temperature and ML engine predictions.

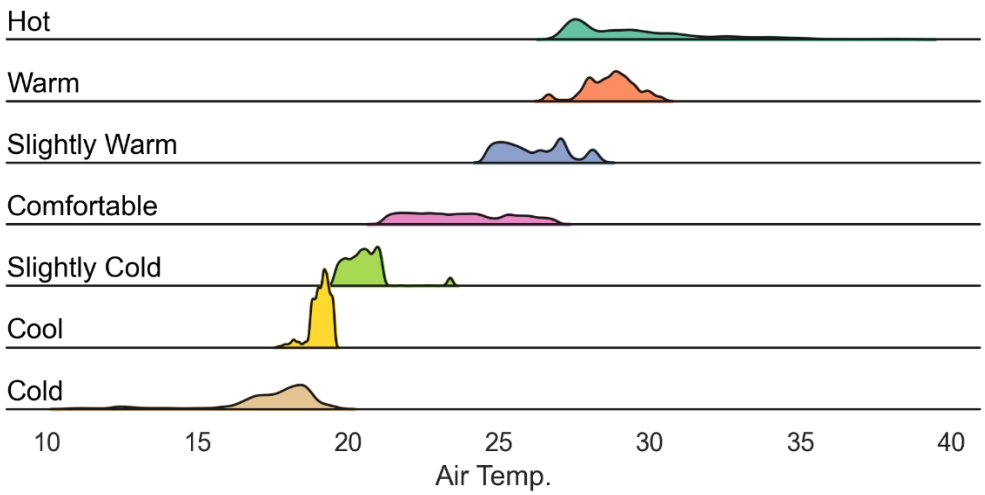


Figure 16: ML Predictions vs Indoor Air Temperature

3.4 Anomaly Detection Engine

3.4.1 Background

3.4.1.1 Objectives and User Story

The primary objective of the Anomaly Detection Engine is to establish a robust, automated system for identifying anomalies in time-series data from office buildings. This system is designed to assist maintenance engineers by providing early detection of unusual patterns that may indicate potential issues such as equipment malfunction, energy inefficiency, or safety hazards. By implementing this system, we aim to enhance operational efficiency, ensure occupant comfort and safety, and facilitate timely maintenance actions. Ultimately, this will lead to reduced operational costs, minimized downtime, and improved sustainability of building operations.

As a maintenance engineer, I rely on the anomaly detection engine to proactively schedule maintenance and address potential issues before they lead to downtime. By identifying anomalies related to energy consumption and activity recognition, this system enables me to ensure that equipment is operating efficiently and that the building environment remains comfortable and safe for occupants. Early detection of anomalies helps prevent equipment failures, reduces energy waste, and supports the continuous, smooth operation of building systems. This proactive approach to maintenance ensures that potential problems are addressed before they escalate, minimizing disruption and maintaining high levels of operational performance.

From a research perspective, the anomaly detection engine seeks to answer the question: "How can a rule-based system effectively identify and categorize anomalies in building operational data to pre-emptively address potential issues related to energy consumption and activity recognition?" This involves exploring the efficacy of simple rule-based logic versus more complex machine learning models, understanding the impact of different thresholds on anomaly detection, and evaluating the system's scalability and performance with large datasets. The research aims to develop a deeper understanding of the balance between simplicity and accuracy in anomaly detection and to identify best practices for implementing such systems in diverse building environments.

3.4.1.2 Model overview and Architecture

The model overview (Figure 17) and architecture (Figure 18) encompass several key components described below and designed to facilitate effective anomaly detection.

1. **Frontend:** The user interface allows users to upload CSV and YAML files, define rules, and view reports. The frontend is designed to be user-friendly, providing intuitive controls and clear visualizations to facilitate the anomaly detection process.
2. **Backend:** The backend is built using Flask, a lightweight web framework that handles file uploads and executes the anomaly detection process. The backend processes the uploaded data, applies the defined rules, and generates detailed reports of detected anomalies.
3. **Data Storage:** Uploaded files and generated reports are temporarily stored on the server, allowing users to download and review the results. The storage system ensures data security and integrity, preventing unauthorized access and data corruption.
4. **Processing Engine:** The core engine is implemented in Python, utilizing Pandas for data manipulation and YAML for rule parsing. The processing engine is designed to be efficient and scalable, capable of handling large datasets and complex rules.
5. **Reporting:** The system generates detailed anomaly reports, which are provided to users as downloadable ZIP files. The reports include comprehensive information about each detected anomaly, helping users to understand and address the identified issues.

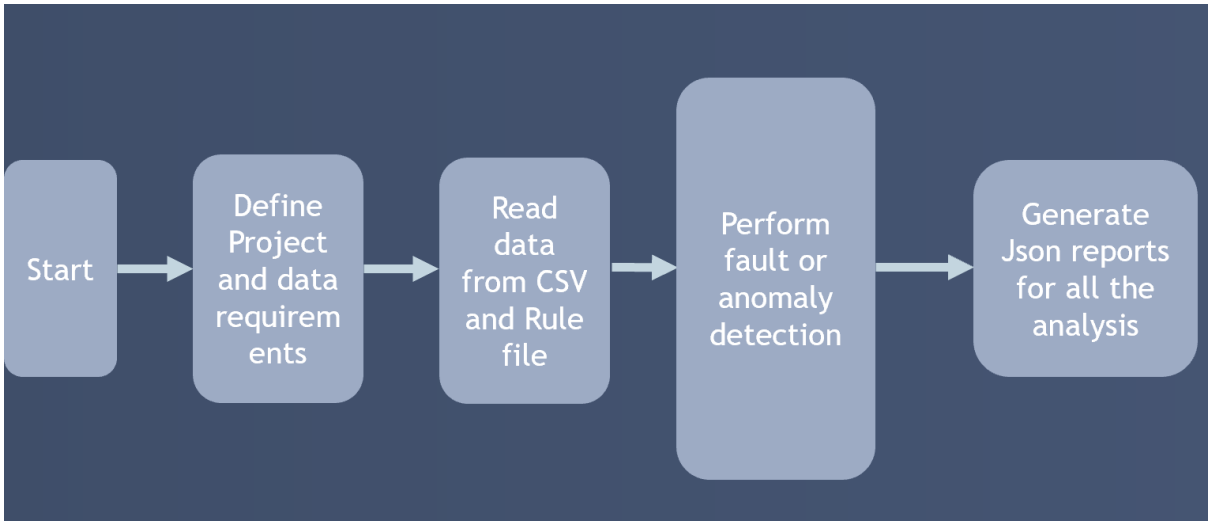


Figure 17: Model Overview Diagram

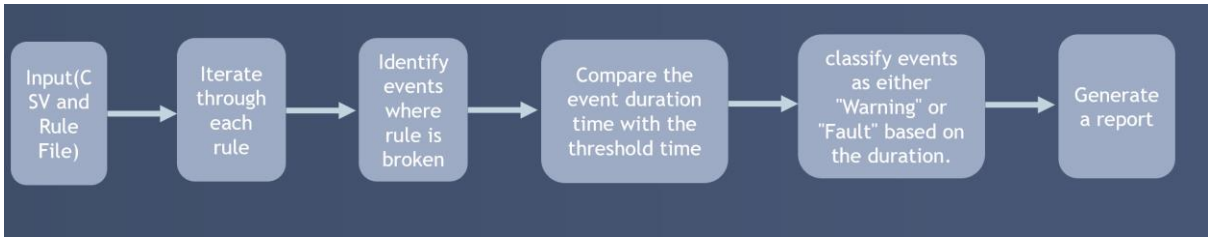


Figure 18: Architectural Diagram

3.4.2 Methodology

The methodology involves a systematic approach to anomaly detection, encompassing data collection, rule definition, data analysis, and reporting. The engine leverages user-defined rules to detect anomalies in real-time data, providing a comprehensive and detailed report for further analysis and action. This approach is designed to be user-friendly, allowing maintenance engineers to easily define their own rules based on the specific needs and conditions of their buildings. This ensures that the system is both flexible and adaptable to various operational scenarios, catering to the unique requirements of different facilities.

The methodology involved the following process steps:

1. **Upload CSV and YAML Files:** Users upload a CSV file containing the time-series data and a YAML file specifying the anomaly detection rules. This allows for a flexible and customizable approach to data input and rule definition, ensuring that the system can be tailored to the specific requirements of each user.
2. **Data Preprocessing:** The system preprocesses the data to handle missing values and ensure consistency and accuracy. This step involves identifying and filling in missing data points, normalizing data ranges, and performing any necessary data transformations to prepare the data for analysis.
3. **Anomaly Detection:** The engine checks each data point against the user-defined rules to identify anomalies. This involves applying the specified thresholds and operators to the relevant columns in the dataset and flagging any data points that violate the defined rules.
4. **Event Recording:** The system records the details of each detected anomaly, including the start and end times, the number of occurrences, and the duration. This detailed record-keeping enables users to track the progression of anomalies over time and to identify patterns or trends that may indicate underlying issues.
5. **Report Generation:** The engine generates a detailed report of the detected anomalies, categorizing them based on severity and duration. This report provides actionable insights for maintenance engineers, allowing them to prioritize maintenance actions and address the most critical issues first.

3.4.2.1 Algorithms and Models

The Anomaly Detection Engine employs a rule-based approach to identify anomalies, leveraging user-defined thresholds and logical operators to detect deviations from expected behaviour. The key components of the system include:

1. **Rule Checking:** For each row in the dataset, the engine checks if it violates any of the defined rules. This involves comparing sensor readings against specified thresholds using operators such as greater than (>) and less than (<). The flexibility of this approach allows users to define a wide range of rules based on their specific needs and operational requirements.
2. **Event Recording:** If a rule is violated, the engine records the event's start and end times, the number of occurrences, and the duration. This detailed event recording provides a comprehensive view of the anomaly, allowing users to understand the context and impact of the detected issue.
3. **Fault Detection:** Events are categorized as warnings or faults based on their duration relative to predefined thresholds. This categorization helps users to prioritize their response actions, focusing on the most critical issues that have the potential to impact building operations or occupant comfort.

3.4.2.2 Data Sources

The data source for the Anomaly Detection Engine includes two primary components:

1. **CSV File:** This file contains the time-series data collected from various sensors and equipment in the office building, including parameters such as CO2 levels, humidity, luminosity, and temperature. The data is

typically collected at regular intervals and stored in a structured format that can be easily processed and analyzed by the anomaly detection engine.

2. **YAML File:** This file contains user-defined rules for detecting anomalies. Each rule specifies the column to check, the operator to use, the threshold value, and the fault threshold duration. The use of YAML for rule definition provides a flexible and human-readable format that can be easily modified and extended as needed.

3.4.2.3 Rules for Anomaly Detection

The following rules were employed for testing the anomaly detection engine:

- **CO2 Levels:**
    - CO2 > 1000 ppm
- **Humidity Levels:**
    - Humidity < 30%
    - Humidity > 60%
- **Luminosity Levels:**
    - Luminosity < 300 lux
    - Luminosity > 500 lux
- **Temperature Levels:**
    - Temperature < 20°C
    - Temperature > 23°C

These rules are defined by users based on operational requirements and comfort standards. The thresholds are crucial as they determine what constitutes an anomaly. Users can adjust these thresholds to better fit their specific needs and contexts, ensuring that the system is both flexible and responsive to changing conditions. In the following figure (Figure 19) an example of the rule file is depicted.

```yaml
# Rule name and conditions
rule_name: Levels in space above or below standard threshold
rule:
  # Condition 1: Check if CO2 levels are above 1000 ppm for more than 10 minutes
  - column: "sensor103|co2"            # Column name for CO2 levels
    operator: ">"                      # Operator to check if CO2 level is greater than threshold
    value: 1000                        # Threshold value for CO2 level
    fault_threshold_duration: 10     # Threshold time in minutes

  # Condition 2: Check if humidity levels are below 30 percent for more than 10 minutes
  - column: "sensor103|humidity"            # Column name for humidity levels
    operator: "<"                    # Operator to check if humidity level is less than threshold
    value: 30                        # Threshold value for humidity level
    fault_threshold_duration: 10     # Threshold time in minutes
```

Figure 19: Example of the rule file

3.4.2.4 Example of the Report

The generated report provides a comprehensive overview of detected anomalies, offering detailed information that helps maintenance engineers to understand and address the identified issues. An example report might include the following information:

- **Rule Name:** "High CO2 Levels"
- **Column:** CO2
- **Rule Logic:** "CO2 > 1000"
- **Number of Events:** 3
- **Start Time of Event:** "2024-01-10 09:15:00"
- **End Time of Event:** "2024-01-10 10:00:00"
- **Event Duration:** 45 minutes
- **Fault:** "Fault"
- **Fault Duration:** 30 minutes

Each entry in the report details the nature of the anomaly, providing maintenance engineers with actionable insights to address the issues. The report categorizes anomalies based on severity and duration, helping users to prioritize their response actions and allocate resources more effectively.

3.4.3 Testing and Results

Table 4: Living Room Monthly Summary

Month	Parameter	No. of Events (Above Threshold)	Total Fault Duration (minutes)	Average Event Duration (minutes)
January	CO2	23	734.81	31.93
January	Temperature < 20	116	1699.98	14.64
January	Temperature > 23	83	1300.98	15.67
January	Humidity	1203	25314.91	313.81
February	CO2	128	4329.95	33.94
February	Temperature < 20	161	3054.95	16.41
February	Temperature > 23	125	1980.0	15.84
February	Illuminance < 100	359	6064.9	16.9

Table 5: Office Monthly Summary

Month	Parameter	No. of Events (Above Threshold)	Total Fault Duration (minutes)	Average Event Duration (minutes)
January	CO2	341	5949.91	17.15
February	CO2	212	6019.97	28.38

- **Living Room:** The summary table for the living room aggregates the data for CO2 levels, temperature deviations (< 20°C and > 23°C), humidity, and illuminance below 100 units, providing insights into the number of events, total fault duration (in minutes), and average event duration (in minutes) for each parameter on a monthly basis (January and February).

- **Office:** Similarly, the office summary table aggregates the data for CO2 levels only, providing the same metrics of number of events, total fault duration, and average event duration on a monthly basis (January and February).

These tables offer a more concise view of the indoor environmental quality parameters monitored in both environments, highlighting the key trends and impacts over the specified months.

3.4.3.1 Testing and Validation

Testing Approach:

1. **Unit Testing:** Each function, such as rule checking, event recording, and report generation, is tested for correctness. Unit tests ensure that individual components of the system work as expected and produce accurate results.
2. **Integration Testing:** The end-to-end workflow, from file upload to report generation, is tested to ensure seamless and error-free operation. Integration tests verify that different components of the system work together correctly and efficiently.
3. **Performance Testing:** The system is tested with large datasets to evaluate its performance and scalability. Performance tests assess the system's ability to handle high data volumes and generate reports in a timely manner, ensuring that it can meet real-world usage scenarios.

Validation Approach: Sample data with known anomalies is used to validate the accuracy of the anomaly detection engine. The detected anomalies are compared with expected results to ensure correctness. Validation ensures that the system accurately identifies anomalies and provides reliable insights for maintenance engineers, enabling them to take proactive measures to maintain optimal building operations.

4 Performance Benchmarking and Evaluation Tool

In this chapter, the Nudge-ready Performance Benchmarking and Evaluation Tool is described as the product of T5.2 of the project. The final results of this task will be presented in D5.2, which will be published in M33 of the project.

Section 4.1 provides a background to this task, including the general methodology and introduction of the three subcomponents of the tool. Section 4.2 provides the implementation of the tool per subcomponent. Section 4.3 describes testing of the tool, and section 4.4 summarizes the feasibility study about the AI techniques and possible applications for the tool, that has been done in this task.

4.1 Background

The Nudge-ready Performance Benchmarking and Evaluation Tool assesses the building's performance by collecting design and as-operated data from the building. This assessment consists of the evaluation of the building's actual performance in comparison to its designed performance, and comparison of its performance with different buildings with similar characteristics. Based on this assessment, the tool provides the user with information and recommendations to improve the performance of their buildings. The user can request this in the Web Platform. The Web Platform "nudges" the tool to provide the results, and finally the results will be presented on the Web Platform, visualized for the user.

To realize this tool, three main functionalities have been identified, and for each a separate subcomponent is designed. These three main functionalities and subcomponents are called Evaluation, Benchmarking, and Recommendation.

In the following subsections, the general methodology, and functionalities of each subcomponent are described.

4.1.1 Methodology

Initial design

Initially elicited use cases of intended functionality by end users are analysed and transformed through use of UML diagrams and User Story workshops. This produces an initial backlog of items to be developed first.

Development

Design and implementation occur in an iterative fashion according to the Agile framework.

The development phase will contain several sprints during which functionality is elicited, designed, implemented and tested. Through intermediate reviews with end-user's feedback is collected to compile work for future iterations. Functional artefacts produced through iterations will be published for integration purposes. At the start of each sprint the backlog of potential functionality is re-evaluated and re-prioritised.

Testing

All developed functionalities are tested both automatically through testing frameworks as well as manually for semantic purposes by the development team. Functional artefacts are published to stakeholders for immediate access and feedback collection.

Instruction

User manuals for the new functionalities are provided where necessary. Technical documentation for APIs is automatically generated and enriched to support consumers in their use. Where necessary, example data can be provided on request.

Validation

Upon achieving a stable product, it is presented for validation to end users representing the target user groups. These end users are asked to attempt the use cases to see if their goals are achieved as described.

4.1.2 Evaluation

Building-level performance indicators are mostly used for rating and certification systems. However, besides building level, it is possible to quantify building energy performance at system level and component level. To assess building performance with a higher resolution, system-level, and component-level evaluations are required. This is possible by increasing adoption of Building Automation Systems (BAS), and Advanced Metering Infrastructure (AMI) [2] . Therefore, in this tool, the objective is to provide a proof of concept to evaluate the building performance not only on the building level, but also on the system level, and to provide recommendations for component level.

The evaluation subcomponent evaluates the performance of the building itself. It compares the total asset and operational EPC scores, in addition to the mutual indicators in both methods, which are the following:

Energy indicators from asset and operational rating calculations (kWh/m^2/year):

- Heating
- Cooling
- DHW
- Lighting

Differences between the asset and operational energy consumption can be caused by multiple reasons as the following:

- Build quality
- Input errors to the model
- Simplification of the building physics in the model
- User behavior
- Different weather conditions from the predictions in the model [3]

It is important that the user understands the difference between two EPC scores. Therefore, the objective of this subcomponent, besides assessing the building performance, is to provide such information to the user, to have a better understanding of these indicators. Such information is provided in the form of metrics and notifications on the web platform. The sequence diagram of this use case is depicted in Figure 20, and the flowchart of this subcomponent is depicted in Figure 21. Connected to this subcomponent, the other two subcomponents will provide complementary information to the user; including comparison of the building's performance with other buildings, and recommendations on how to improve its performance.

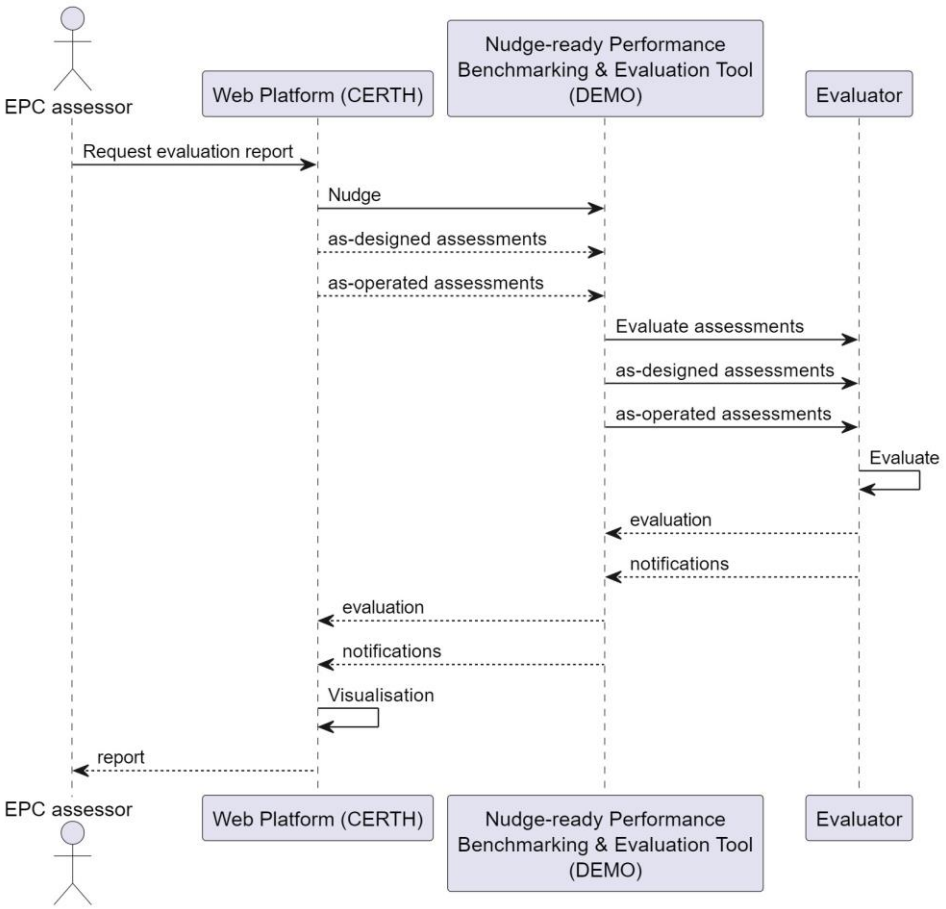


Figure 20: Sequence diagram of evaluation use case

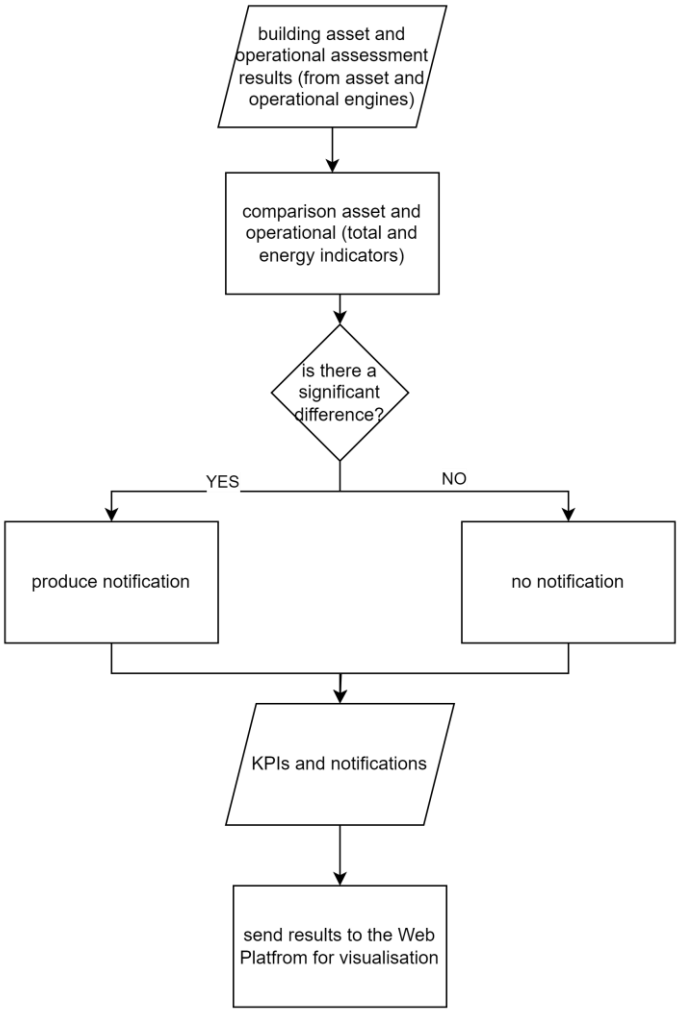


Figure 21: Flowchart of evaluation subcomponent

4.1.3 Benchmarking

Benchmarking is used to refer to the comparison of building energy performance with that of similar buildings. Empirical benchmarking is used to compare the actual building energy performance with the broader building market [4]. This subcomponent will provide a comparative assessment of the building performance with similar buildings in different categories. The benchmarking subcomponent will be based on the similar tool in the Horizon 2020 project D^2EPC. The updates and integration of this subcomponent will be provided in D5.2. The sequence diagram of this subcomponent is depicted in Figure 22.

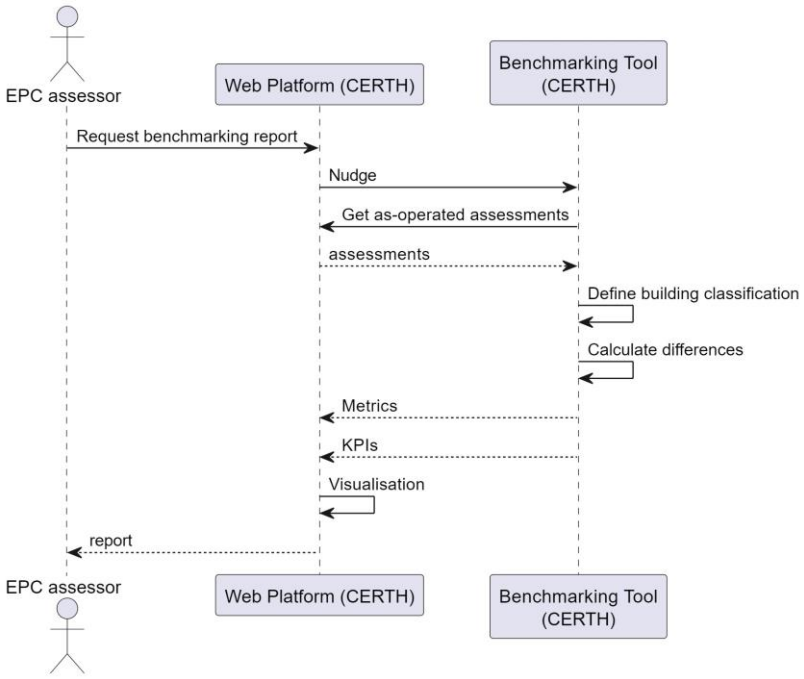


Figure 22: Sequence diagram of benchmarking use case

4.1.4 Recommendation

This subcomponent provides recommendations on three parts as described in the subsections below.

4.1.4.1 Energy Upgrades

By assessing and benchmarking the building performance, the user is provided with a general evaluation. In connection to that, this part of the recommendation subcomponent provides a general EPC improvement recommendation based on the operational indicators. So that the user can have an overview of the improvement of the EPC score of their building, by selecting different indicators to be improved. The user can use this part of the recommendation, to decide which indicators, and hence which practices, are required to receive a higher rating in the EPC score. The sequence diagram of this use case is depicted in Figure 23, and the flowchart of this subcomponent is depicted in Figure 24.

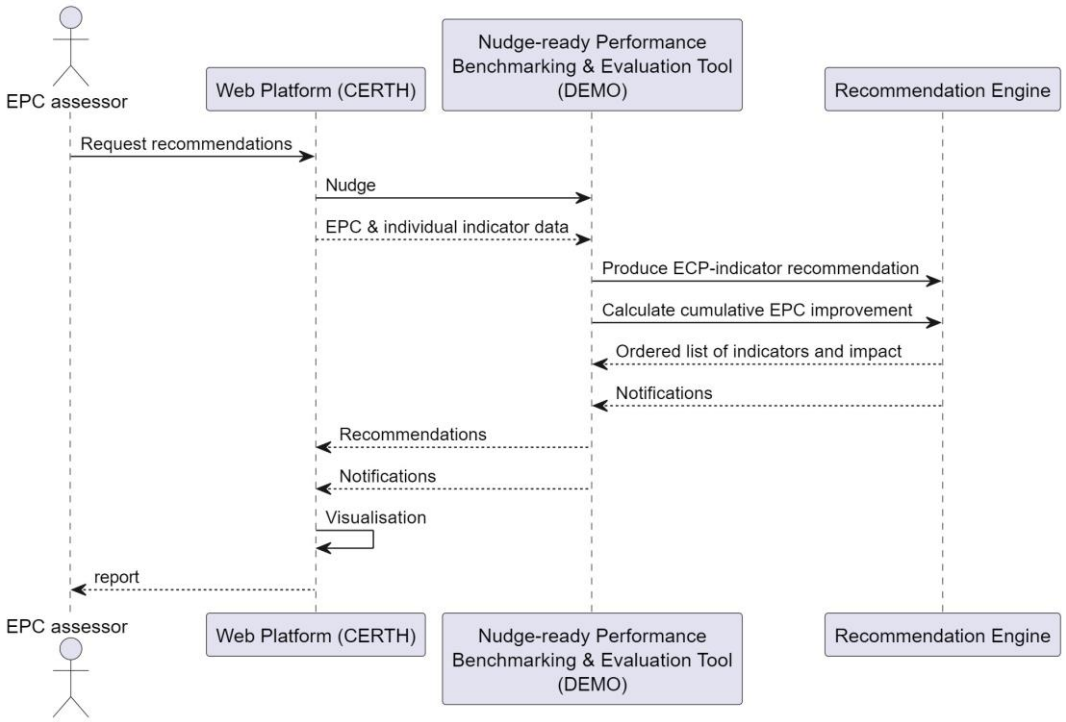


Figure 23: Sequence diagram of recommendation use case 1

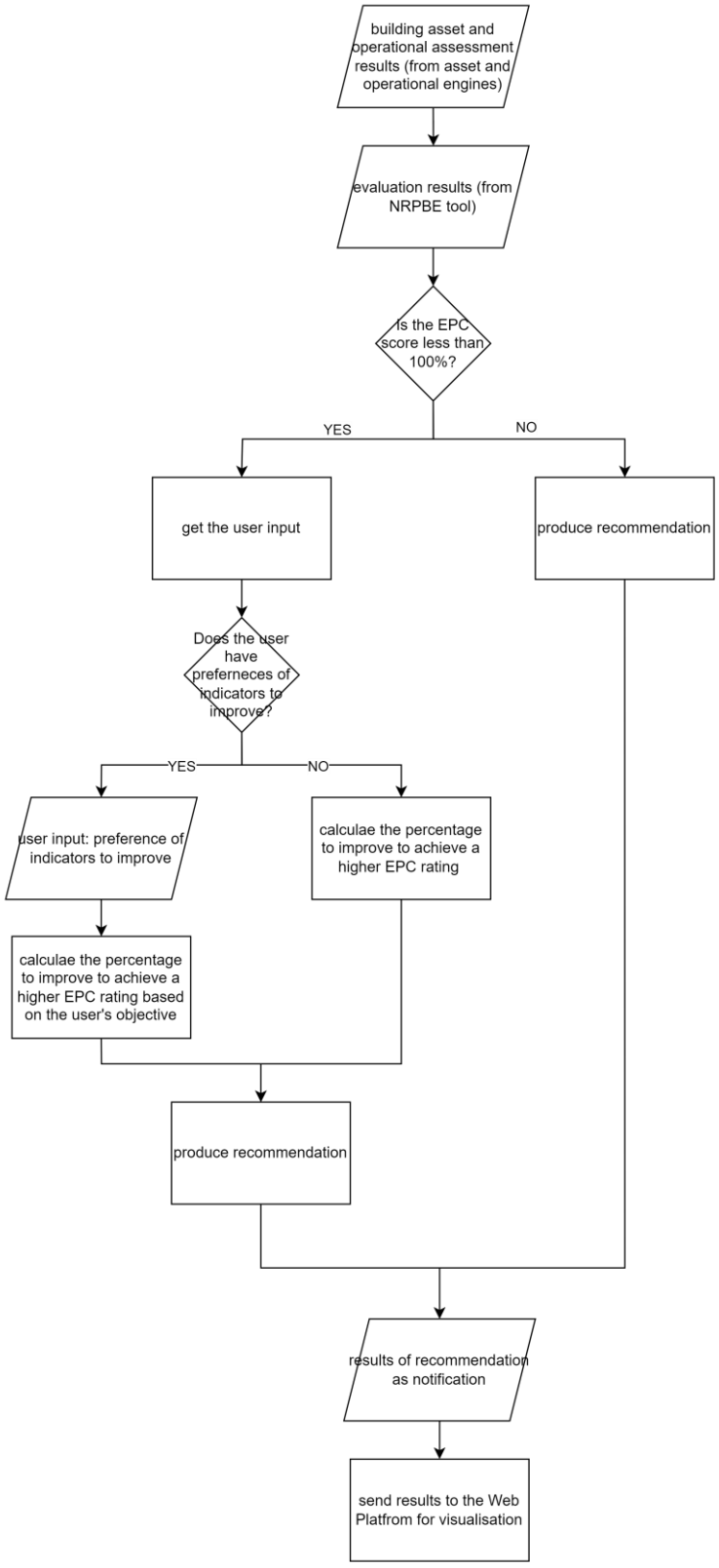


Figure 24: Flowchart of recommendation subcomponent - part 1

4.1.4.2 Energy Efficiency

This part of the recommendation subcomponent focuses on energy performance improvement by replacing the technical systems to ones with higher energy efficiencies. As a result of this recommendation, the user is provided with the prediction of energy consumption (heating, cooling, lighting, or DHW) with the new technical system, and hence the predicted improvement in the EPC score.

Energy use KPIs evaluate the efficiency of delivering the service of a building system with a certain amount of energy consumption. The common energy use related KPIs are Energy Use Intensity (EUI), and Energy Efficiency (EE).

- EUI: cumulative energy consumption as a function of normalizing factor, with various normalizing factors depending on the specific KPI (e.g. annual lighting energy consumption/ building floor area)
- EE: ratio of served energy to the consumed consumption (e.g. delivered cooling energy/ consumed electricity)

The energy consumption prediction of a new system is using both abovementioned indicators, calculated based on the current operational energy consumption, energy efficiency of the current system, and the energy efficiency of the new system, by taking the following assumptions:

- Energy Efficiency= Energy Output / Energy Input
- Current Operational (e.g. heating) Consumption × Current Energy Efficiency = Current Energy Output
- Current Energy Output × New Energy Efficiency = New Energy Input
- New Energy Input = Predicted Operational (e.g. heating) Consumption

The user is provided with a set of predefined alternative systems, with required data (energy efficiency and costs), from which they can choose. It is also possible that the user provides their own alternative for replacing a technical system. The sequence diagram of this use case is depicted in Figure 25, and the flowchart of this subcomponent is depicted in Figure 26

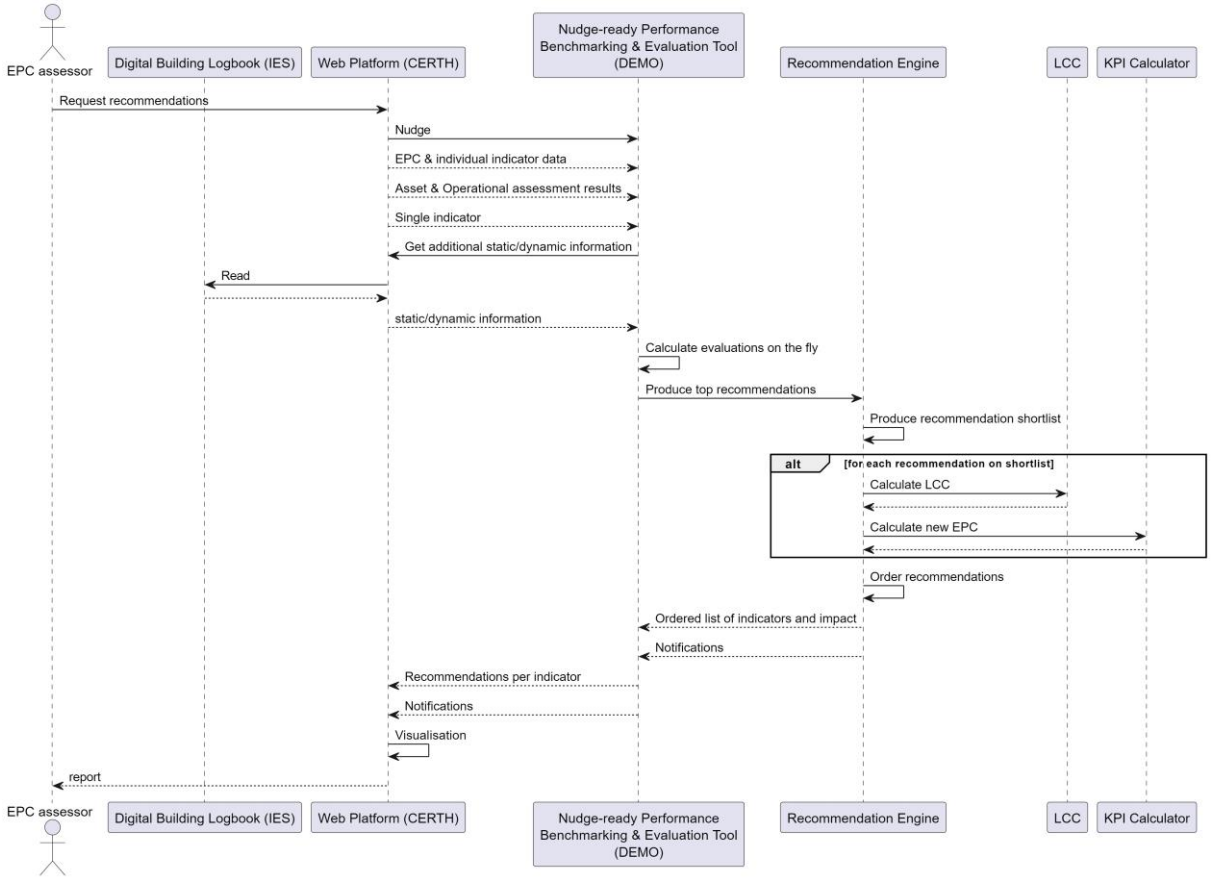


Figure 25: Sequence diagram of evaluation use case 2 &

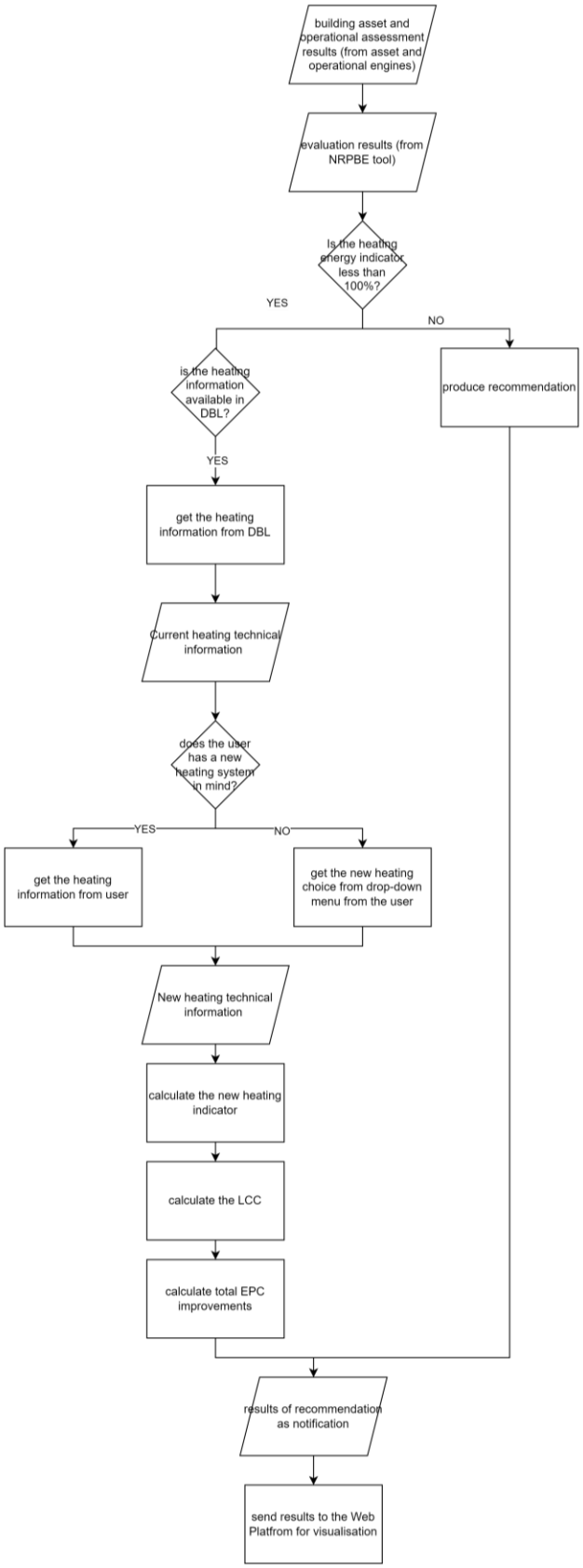


Figure 26: Flowchart of recommendation subcomponent - part 2 & 3

4.1.4.3 Optimal Operation and Maintenance

The final part of the recommendation provides the LCC of the new system of choice, considering investment and O&M costs. It is also possible for the user to make comparison between different alternatives. The sequence diagram of this use case is depicted in Figure 25, and the flowchart of this subcomponent is depicted in Figure 26Figure 24.

As a result, the user will be provided by a set of financial indicators to make an informed decision for replacing a technical system. The results will be visualized on the web platform. An example is visualized in Figure 27 and Figure 28. The financial indicators are as follows:

Net Present Value (NPV):

To consider the costs in the different stages that they occur, the Net Present Value is used to calculate the sum of present value of the stream of the future costs and benefits, using the following formula:

$$NPV = \sum(Cn \times q) = \sum_{n=1}^{p} \frac{Cn}{(1+d)^n}$$

Where:

NPV	=	Net Present Value
C	=	Cost in year n
q	=	Discount factor
d	=	Expected real discount rate per annum
n	=	Number of years between the base date and the occurrence of the cost
p	=	The period of analysis

Net Savings (NS):

The indicator quantifies the financial savings achieved through energy-efficient measures. It compares the energy cost of the new energy costs and the current energy costs, calculated by the following formula:

$$NS_{A:BC} = \sum_{t=0}^{N} \frac{S_t}{(1+d)^t} - \sum_{t=0}^{N} \frac{\Delta I_t}{(1+d)^t}$$

Where:

$NS_{A:BC}$	=	NS, in PV Euros, of alternative (A), relative to base case (BC)
S_t	=	Savings in year t in operational costs associated with the alternative
ΔI_t	=	Additional investment related costs in year t associated with the alternative
t	=	Year of occurrence (where 0 is the base date)
d	=	Discount rate
N	=	Number of years in study period

Savings-to-Investment Ratio (SIR):

The indicator measures the ratio of energy and operational savings to additional investment costs, calculated for the energy saving alternative relative to the current situation. This indicator is used to rank alternatives. The SIR is calculated by the following formula:

$$SIR_{A:BC} = \sum_{t=0}^{N} \frac{S_t}{(1+d)^t} \Big/ \sum_{t=0}^{N} \frac{\Delta I_t}{(1+d)^t}$$

Where:

$SIR_{A:BC}$	=	SIR of alternative (A), relative to base case (BC)
S_t	=	Savings in year t in operational costs associated with the alternative
ΔI_t	=	Additional investment related costs in year t associated with the alternative
t	=	Year of occurrence (where 0 is the base date)
d	=	Discount rate
N	=	Number of years in study period

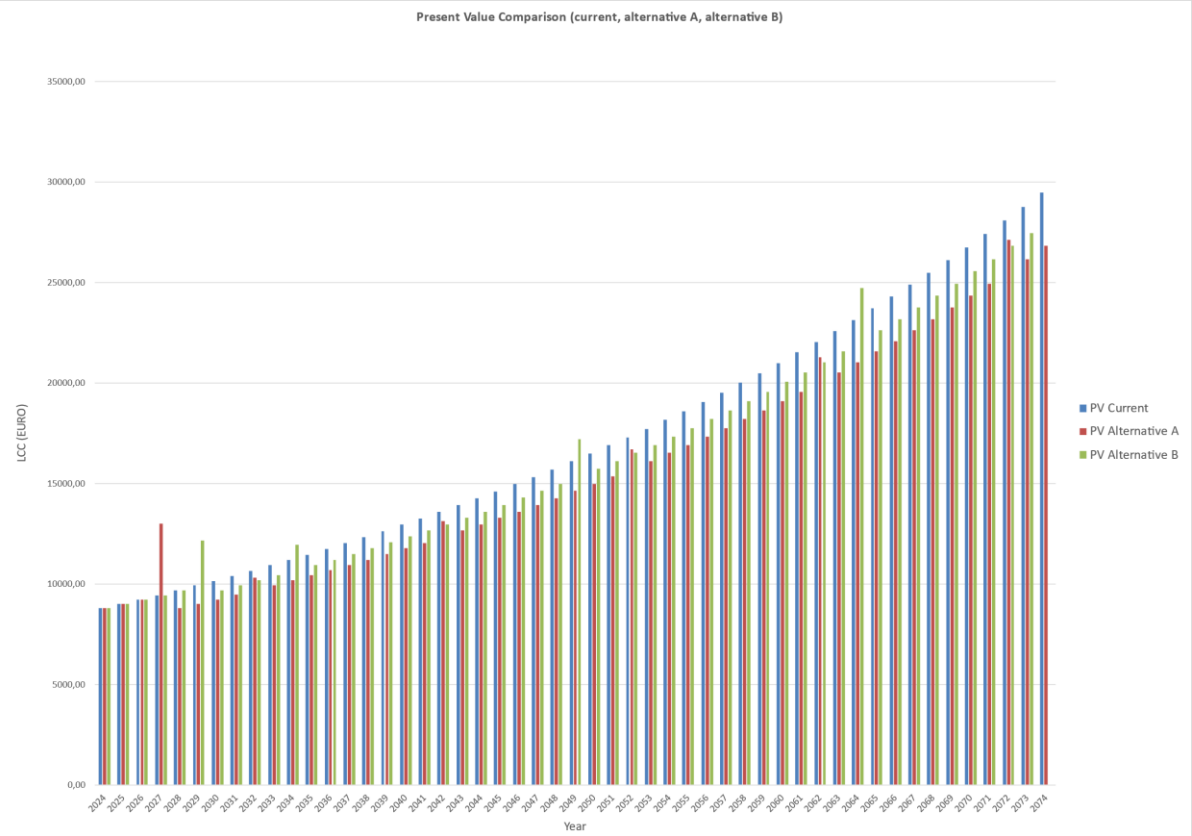


Figure 27: Example of the visualization of LCC Calculation for different alternatives

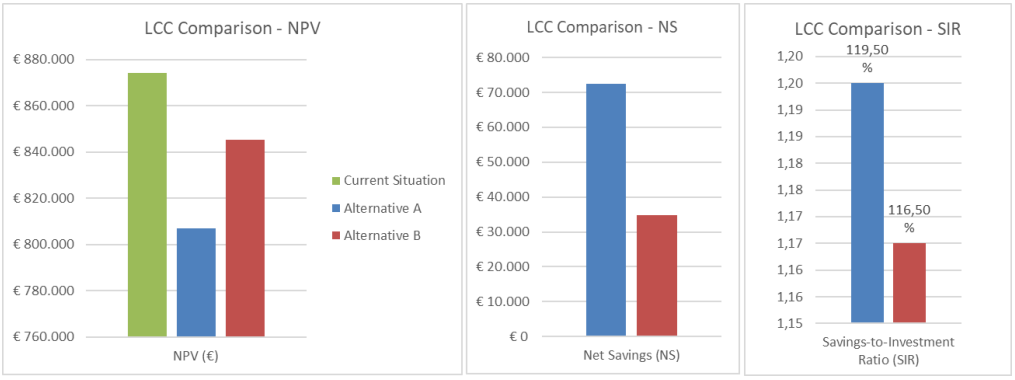


Figure 28: Example of the results of LCC comparison for different alternatives

4.2 Implementation

All functionalities stemming from the defined use cases are decomposed into user stories with appropriate acceptance criteria. User stories are implemented in an iterative approach (Agile), resulting in incremental growth of the Nudge-ready Performance Benchmarking and Evaluation Tool. Intermediate review allows for early adjustment of the development strategy if necessary.

The Nudge-ready Performance Benchmarking and Evaluation Tool is an extension of the RE Suite software solution. This allows re-use of existing software components and functionalities. Specifically, the tool is an extension of the RE Suite WebService, one of its main components for interaction over the web through HTTPS and RESTful-like APIs. Given its nudge-ready character, the tool is a good fit.

The full API is documented through OpenAPI standards and available as interactive Swagger documentation.

Figure 29: Component API documentation

In general all endpoints of the Nudge-ready Performance Benchmarking and Evaluation tool adhere to the following conventions.

- Data is communicated in JSON-format
- A successful request returns a 200 OK response
- A non-successful request returns a 4xx or 5xx response

The Nudge-ready Performance Benchmarking and Evaluation component is designed as a back-end component to be integrated in the Web Platform. As such, visualisation of results is not one of its responsibilities although suggestions are included.

Communication with the API is secure and encrypted through the HTTPS protocol using signed certificates. Use of the API is only available to authorised users, authenticated through the Basic Auth method.

4.2.1 Evaluation

The evaluation component compares the provided as-designed and as-operated performance indicators and draws preliminary conclusions. As such, required input parameters through the request body the relevant indicators. Its endpoint is `POST /SLEPC/NRPBE/evaluat.`

Evaluation request (input)

```
{
    "asDesignedIndicators" : [
        {
            "Name" : "Heating",
            "Value" : 99.5
        },
        ...
    ],
    "asOperatedIndicators" : [
        {
            "Name" : "Heating",
            "Value" : 77.2
        },
        ...
    ]
}
```

The evaluation component can only compare semantically equivalent indicators. For simplicity's sake, it is assumed that such indicators are similarly named. Should this prove erroneous a simple adjustment can be made to map indicators based on predefined convention.

The output of the evaluation component is a list of comparison results as well as relevant notifications. For sake of completeness the relevant indicator, input values are repeated back in the output.

Evaluation response (output)

```
{
    "evaluations": [
        {
            "name": "Heating",
            "asDesignedValue": 99.5,
            "asOperatedValue": 77.2,
            "comparison": -0.2241206030150753
        }
```

```
    ],
    "notifications": [
        {
            "type": "Warning",
            "title": "Heating has significantly decreased",
            "message": "The operational assessment for Heating is 22,4% lower than its as-
designed assessment."
        }
    ]
}
```

The comparison result is a simple differential percentage of as-operated performance versus as-designed performance. The resulting notifications use a simple threshold comparison to indicate if a difference in performance is significant or not. Currently the thresholds are set to larger than ±5% to produce a notification and larger than ±15% to consider a difference significant. Real-world application should be used to tweak these thresholds for improved conclusions.

4.2.2 Benchmarking

For benchmarking purposes a basis exists in the benchmarking tool from the Horizon 2020 project D^2EPC. It is a web-based component capable of calculating and visualizing the as-operated performance of a building compared to buildings of similar class. To do this, it makes use of a synthetic dataset of 1000 buildings for comparison purposes, clustered through a clustering algorithm. Additionally, insight into the dataset and its clusters is visualized through relevant statistics and graphs.

The existing tool is updated and integrated for compatibility with the SLEPC project. Additionally, it is extended with indicators and visualizations specific to SLEPC.

4.2.3 Recommendation

4.2.3.1 EPC-improvement recommendations

The EPC-improvement recommendation component calculates what indicators could result in the most improvement to the overall EPC. It takes into account the current EPC-indicator values as well as optionally the weight used to calculate the EPC. Its endpoint is `POST /SLEPC/NRPBE/recommend-epc-indicators`

EPC-improvement recommendation request (input)

```
{
    "epc" : {
        "score" : 63.5,
        "indicators" : [
            {
                "Name" : "Heating",
                "Value" : 63.5,
                "Weight" : 1.0
            },
            ...
        ]
    },
    "classification" : "Dutch"
}
```

The EPC score nominator is calculated from sumproduct of all indicator values and weights. As such, the potential improvement for a specific indicator to the total EPC score is based on the converse value: subtract the indicator value from its theoretical maximum and apply the same formula. This yields a potential improvement for the indicator to the total EPC score in percentage points.

While the theoretical maximum for any indicator is 100%, it is assumed to be significant effort to improve an indicator in the 90th percentile, compared to an indicator with a lower value. As such, the theoretical maximum is set to 90% for those with values below. When comparing indicators, those above 90% are weighted significantly lower than those with 'easier' room for improvement.

The resulting EPC score percentage points are sorted in descending order, resulting in a list of indicators with the most significant potential for improvement at the top. A cumulative sum starting from the current total EPC score yields a steadily increasing total EPC score as indicators are improved.

If a classification method is known and supported, the cumulative EPC score can be converted into a class. In this way, it is known exactly how many indicators need improvement to increase the class rating.

The output contains the ordered list of indicators, with their improvement potential. The current value and weight as provided in the input are repeated in the output. Additionally, the output contains a list of textual notifications.

EPC-improvement recommendation response (output)

```
{
    "indicators" : [
        {
            "name" : "Heating",
            "value" : 63.5,
            "weight" : 1.0,
            "potential" : 26.5,
            "epcIncrement" : 2.55,
            "epcCumulative" : 65.8,
            "epcClass" : “B”,
        }
    ],
    "notifications" : [
        {
            "type" : "Info",
            "title" : "Improving EPC-class to B",
           "message" : " The EPC class can be improved from C to B by improving the Heating
indicator."
        }
    ]
}
```

Conclusions on top potential and recommendations for class improvement are verbalized in the form of textual notifications. These can then be visualized as advice to the user.

While the current result is static based on user input, the decomposed setup allows for improvement in the future. A number of ideas are considered, though not implemented at the time. One is to allow users the option to remove indicators from consideration for a more personalized list of results. A second potential improvement would allow the user full flexibility by providing them with an interactive user interface, allowing them manual sorting options to prioritize certain indicators over others. For true flexibility the user could set their own theoretical maximum per indicator.

4.2.3.2 Detailed indicator recommendations

Zooming in on a specific indicator allows for concrete, detailed recommendations for improvement of the building. This component consults a database of potential improvements and estimates returns the best ones, with financial information if possible. A full workflow for the Heating indicator is implemented as a proof-of-concept. Its endpoint is `POST /SLEPC/NRPBE/recommend-indicator-details`

Detailed indicator recommendation request (input)

```
{
    "object" : 1234,
    "indicator" : {
        "Name" : "Heating",
        "Value" : 63.5,
        "Weight" : 1.0
    },
    "epc" : {
        "score" : 63.5,
        "indicators" : [
            {
                "Name" : "Heating",
                "Value" : 63.5,
                "Weight" : 1.0
            },
            ...
        ]
    },
    "classification" : "Dutch"
}
```

The component takes the input object identifier and uses it to consult the Digital Building Logbook through the Web Platform to acquire more information on the building and its current systems. It then consults its own database of potential recommendations for those that could apply, including system replacement. It produces a shortlist based on rough exclusion criteria and a simple improvement estimate based on floor area.

The top three recommendations are considered as candidates. For these a new indicator value is calculated, as well as its impact on the EPC total.

The potential recommendations contain information on initial and cyclic (maintenance) costs. As such, they can be projected over time in an LCC. This results in a financial projection and a total impact over a number of years. If an LCC is available for the current state of the building this is a basis for comparison, as well as optimization. In this case, it is possible to recommend a moment of application for the recommendation based on its financial impact and system longevity. By default, total financial impact is projected over a period of 50 years.

The implementation of the LCC calculation relies heavily on the existing LCC module within the RE Suite solution of tools. It requires LCC data to be pre-loaded in RE Suite for full functionality of the proof-of-concept.

The output is a list of recommended measures, including new EPC values and LCC details per measure. Additionally, the output contains a summary of the current LCC, and a list of notifications.

EPC-improvement recommendation response (output)

```
{
    "measures" : [
        {
            "name" : "Replace heating system with <model>",
            "description": "...",
            "newIndicatorValue": 63.5,
```

```
            "weight": 1.0,
            "epcIncrement": 2.55,
            "epcCumulative": 65.8,
            "epcClass": “B”,
            "lcc" : {
                presentValues : [
                    {
                        "year" : 2024,
                        "value" : 6123.0
                    },
                    ...
                ],
                netPresentValue : 1234.5,
                netSavings : 55.3,
                savingsToInvestmentRatio : 12.3
            }
        }
    ],
    "currentLcc" : {
        presentValues : [
            {
                "year" : 2024,
                "value" : 6123.0
            },
            ...
        ],
        netPresentValue : 1234.5,
    },
    "notifications": [
        {
            "type": "Info",
            "title": "Replace heating system",
              "message": "The EPC can be improved by 12% by updating your heating system from X to Y."
        }
    ]
}
```


While the current result is static based on user input, the decomposed setup allows for improvement in the future. A number of ideas are considered, though not implemented at the time. One is to allow the user to choose their replacement system from a list and see the impact of the chosen system directly. Additionally, support for missing information, such as manually filling out heating system information would allow an impact estimate for systems not in the original database.

4.3 Testing

At the lowest level developed components are unit-tested during development. All unit tests are retained and periodically run to ensure functionality is retained and no regression occurs. Additionally, developers manually test new functionality. A code review process ensures a second developer reviews the system on a technical level and manually tests new functionality with an unbiased viewpoint.

Where necessary mock and dummy services are introduced to allow testing without impact from dependencies. For example, the dependency on the Digital Building Logbook for detailed indicator recommendations is mocked through an expected response to request system.

A predefined request-response collection through PostMan contains end-to-end tests for automated tests of the system. These are periodically run.

The iterative character of the development process yields (blocks of) increments in sprints. These results are periodically reviewed by domain experts. This serves as verification as well as an opportunity for strategy adjustment for the remaining development.

4.4 AI Pre-feasibility Study

The increasing demand for energy-efficient and sustainable buildings necessitates integrating advanced AI techniques in building performance simulation and optimization. Artificial Neural Networks (ANNs) and metaheuristic algorithms are useful in this domain, particularly in enhancing the calculation and assessment of EPCs. Therefore, this section provides the prefeasibility study that has been done on the available methods, which can be considered as future works in this or future projects.

ANNs can predict energy consumption based on many building parameters and external conditions. This predictive capability empowers stakeholders to develop more precise and tailored energy management strategies. Concurrently, multi-objective optimization algorithms evaluate trade-offs among competing objectives, such as energy efficiency, occupant comfort, and environmental impact. This approach ensures that building performance assessments are well-informed and balanced, leading to more effective decision-making processes.

In this study, the available AI techniques have been investigated to see if they can be utilized. This prefeasibility study is out of the scope of T5.2, however, it is considered as a valuable addition to the work of this task. The main benefits of the studied techniques are energy consumption forecast, and multi-objective optimization for recommendations (based on the objectives of the user, such as budget, LCA, etc.). The techniques are not implemented in the development of the tool. However, if there is enough added value, they might be implemented in the second phase of the task.

4.4.1 Introduction to Multi-Objective Optimization Integration

The increasing demand for energy-efficient and sustainable buildings necessitates integrating advanced AI techniques in building performance simulation and optimization. ANNs and Multi-Objective Optimization (MOO) can be used to enhance the calculation and assessment of EPCs.

MOO involves solving problems that have two or more conflicting objectives. In the context of building performance, these objectives often include minimizing energy consumption, maximizing indoor thermal comfort, reducing environmental impact, and minimizing operational costs. The primary goal is to find a set of optimal solutions, known as the Pareto front, where no objective can be improved without compromising at least one other objective [5].

For instance, consider optimizing indoor comfort and window size alongside energy consumption. Larger windows may enhance natural lighting and occupant comfort but can also increase energy consumption due to greater heat loss or gain. MOO algorithms help navigate these trade-offs, identifying solutions where an improvement in one objective (e.g., comfort) does not lead to an unacceptable deterioration of another (e.g., energy use).

4.4.2 Integration of Advanced AI Techniques

A multi-objective optimization model was proposed to determine buildings' optimal or near-optimal design under given conditions [6]This proposed model describes how combining ANN with NSGA-II reduces energy demand and thermal discomfort.

- ANN Prediction: ANNs are trained on extensive datasets to predict building performance metrics (e.g., energy consumption and thermal comfort levels) based on various design parameters (e.g., insulation, window size) and operational factors (e.g., occupancy, weather). This offers a rapid estimation method crucial for efficient optimization.

- NSGA-II Optimization: NSGA-II leverages the ANN predictions to explore a vast design space, identifying Pareto-optimal solutions that represent the best trade-offs between competing objectives.

ANNs can predict energy consumption based on various building parameters and external conditions, aiding the MOO process. This predictive function enables stakeholders to develop initial energy management strategies. Concurrently, MOO algorithms, informed by ANN predictions, enable an evaluation of trade-offs.

To illustrate, consider a multi-objective optimization problem focused on balancing energy consumption (E) and occupant comfort (C), both influenced by window size (W):

$$\text{Minimize } \mathrm{E}(\mathrm{W}) \ \& \text{Maximize } \ \mathrm{C}(\mathrm{W})$$

Subject to constraints:

$$\mathrm{W}_{\min} \leq \mathrm{W} \leq \mathrm{W}_{\max}$$

$$\mathrm{C}(\mathrm{W}) \ = \ \mathrm{d} \backslash \log(\mathrm{W} \ + \ 1) \ + \ \mathrm{e}$$

To enhance the energy consumption model E, we can incorporate factors like solar heat gain, conduction through the building envelope, and internal heat sources:

$$\mathrm{E}(\mathrm{W}) = \mathrm{a}_1\mathrm{W}^2 + \mathrm{b}_1\mathrm{W} + \mathrm{c}_1 + \mathrm{a}_2\mathrm{Q}_{\mathrm{solar}}(\mathrm{W}) - \mathrm{b}_2\mathrm{R}_{\mathrm{envelope}} + \mathrm{c}_2\mathrm{Q}_{\mathrm{internal}}$$

Where:

$Q_{\mathrm{solar}}(W)$ is the solar heat gained through the window (dependent on W).

R_{envelope} is the thermal resistance of the building envelope.

Q_{internal} is the internal heat generated by occupants and equipment.

The coefficients ai, bi, and ci are derived from building simulations or physical models.

By incorporating this example energy equation, the MOO process gains greater fidelity in capturing the complex interaction of factors that influence building energy performance. ANNs can be used to model the relationship between W, environmental conditions, and the various components of E. This enables the optimization process and guides the selection of window sizes that effectively balance energy efficiency and occupant comfort.

The Key Advantages of this method are as follows:

- Efficiency: ANNs excel at processing large datasets and capturing complex relationships, reducing the time required for computationally intensive simulations.
- Flexibility: This integrated approach is adaptable to various building types and operational conditions, making it versatile for diverse optimization tasks.

4.4.3 Methodology

The approach presented in Figure 30 is designed to address this challenge while meeting the requirements of energy-efficient buildings.

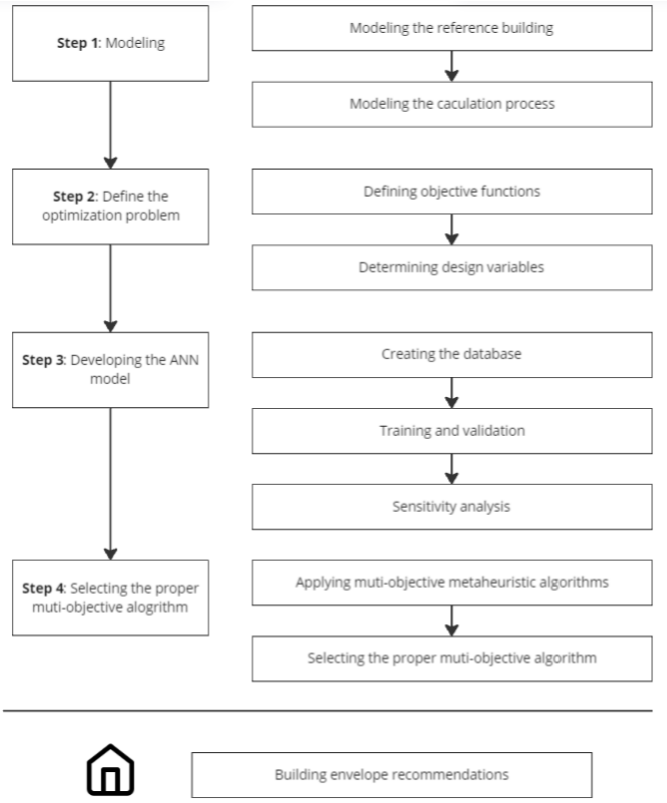


Figure 30: Flowchart of the optimization approach

Data Collection and Pre-processing

Data Sources:

- Building Information Models (BIM): Extract building geometry, thermal properties, and system specifications.
- Historical Data: Retrieve past energy consumption data, IEQ measurements, and weather data from IoT sensors and databases.
- Data Formats: Utilize standardized JSON formats for input data, including building parameters, energy measurements, and device specifications.

Data Pre-processing

Data is validated, cleaned, and transformed to ensure consistency and completeness, including handling missing values and normalization.

Simulation and Database Creation

- Dynamic Thermal Simulation (DTS): EnergyPlus performs detailed simulations, accounting for internal/external heat gains, thermal inertia, and envelope properties.
- Synthetic Database: A comprehensive database is created from DTS outputs, covering various design variable combinations.
- Energy Modelling: The synthetic database generates energy models from EnergyPlus for training ANNs.

Artificial Neural Networks (ANNs) for Prediction

Model Architecture: Design ANN architectures suitable for predicting building performance metrics. Depending on the complexity of the data and the specific prediction tasks, such as multi-layer perceptrons (MLPs), convolutional neural networks (CNNs), and recurrent neural networks (RNNs).

Training and Validation

- Train ANN models using the training set for energy evaluations, such as user inputs, and validate their performance using physical-based simulations like EnergyPlus.
- Evaluate model performance using metrics such as Root Mean Square Error (RMSE) and correlation coefficient (R).

Sensitivity Analysis

Garson's algorithm is employed to assess the impact of different input variables on the objective functions.

Multi-Objective Optimization (MOO) Framework

- Objective Functions: Define objective functions for optimization, such as annual thermal energy demand and the weighted average of discomfort degree-hours.
- Multi-Objective Optimization: Metaheuristic algorithms like NSGA-II to find optimal or near-optimal building designs under given constraints.
- Decision Support Systems: Implement decision support systems to help stakeholders interpret optimization results. Visualize the Pareto front and provide insights into trade-offs between different objectives.

5 SLEPC Visualization Platform

5.1 Requirements

The tables below presents the fundamental functional requirements that have been met for the SLEPC Web Platform, as documented in D1.3. The aim of these tables is to detail the platform's operational characteristics, the involved components, the primary rationale behind their design, and the criteria used for their evaluation.

Table 6: Web Platform related functional requirements SLEPC asset methodology

ID	Description	Rational	Origin/ Source	Fit Criterion	Priority
SLEPC[3]-1	The platform should have access to a meteorological climate database to facilitate SLEPC asset rating calculation in the absence of real-time data.	Need to develop an interface for reading local climate data from a database upon request.	D1.1	Weather information that is required to complete the assessment should be retrieved either from real-time data or a meteorological climate database.	Medium
SLEPC-2	The platform ought to issue an SRI certificate based on European Union (EU) methods A and B, in accordance with EPBD directive.	There are not any commercial calculation engines for delivering SRI certificates.	DoA T2.1	Providing SRI certificates.	Critical
SLEPC-3	The linkage of SRI certification with the EPC data is also attempted.	To make the procedure quicker for the end user, some of the SRI's necessary data could be retrieved via EPC data.	DoA T2.1	Get EPC information, maybe generic building information, to complete the SRI forms.	Medium
SLEPC-4	Extraction of the highest possible amount of information from the IFC file for the SRI calculation	Creation of a BIM file parser for enabling the use of BIM documents for the extraction of EPCs.	DoA T2.1	Use of BIM files for the extraction of SRI.	Major
SLEPC-5	The platform should be able to perform energy and non-energy resources analysis, according to the SLEPC developed methodology.	Need to develop a module for calculation based on Energy Performance of Buildings Directive (EPBD EN52000 standards series and integrate outputs to SLEPC asset rating calculation methodology (T2.6).	DoA, T2.2	The SLEPC asset rating must include the Energy and non-energy analysis in its final assessment results.	Major
SLEPC-6	The energy and non-energy resources assessment are conducted in BIM environment, enabling in this manner the development of all required APIs for this purpose.	Achieve a comprehensive energy and non-energy asset assessment of the building, which is further integrated into the SLEPC rating scheme.	DoA, T2.2	The creation of APIs for the conduct of energy and non-energy resources assessment in BIM environment.	Major

SLEPC-7	The platform should be able to allow inputs from periodic technical audits and inspections, according to the SLEPC developed methodology.	Need to develop an integrated database and interface to collect input data and a calculation module to correct existing calculated/estimated values, and integrate outputs to SLEPC asset rating calculation methodology (T2.6).	DoA, T2.2	Technical audit and inspection data will be made accessible to fill up any input data gaps that may exist.	Major
SLEPC-8	The platform should be able to perform an Environmental life-cycle assessment according to the developed procedure in T2.3.	Need to develop a module for calculation based on the Level(s) scheme for quantifying the environmental impact of the building and integrate outputs to SLEPC asset rating calculation methodology (T2.6).	DoA, T2.3	The web-dashboard should provide the end-user with information on environmental aspects.	Critical
SLEPC-9	The environmental assessment of buildings is implemented with the use of BIM documents.	The use of BIM files facilitate the calculation processes.	DoA, T2.3	The required APIs that extract the required building information from ifc documents are also being developed.	Major
SLEPC-10	The platform should be able to perform asset building complex assessment, according to the developed procedure in T2.5.	Need to develop a module for calculating the effects and interactions with neighbouring buildings and systems, and integrate outputs into the SLEPC asset rating calculation methodology (T2.6).	DoA, T2.5	Creation of a new asset EPC for Building Complexes.	Major
SLEPC-11	The platform should be able to perform SLEPC asset rating, according to the developed procedure in T2.6.	Need to develop a module for SLEPC assessment based on SRI scheme, energy and nonenergy analysis, LCA, Levels(s), building systems energy auditing and building complex assessment.	DoA, T2.6	Compare the output of each individual rating with those exported from corresponding commercial software.	Critical

Table 7: Web Platform related functional requirements - SLEPC framework operational methodology

ID	Description	Rational	Origin/ Source	Fit Criterion	Priority
SLEPC-12	The tool should calculate EN 16798-1 categories (I, II, III, IV) for IEQ assessment, for thermal comfort and indoor air quality.	These non-energy/Levels/IEQ are mentioned in many places, but most specifically in T3.1. One implementation is available in Aldren TAIL, but these are temperature and CO2 data processing algorithms with occupancy detection.	DoA, T3.1	Determine the indicators' validity in relation to actual conditions by calculating and contrasting these indicators with contextual data gathered at the pilot locations over time, such as heating/cooling energy consumption, indoor	Major

				ambient temperature, etc.	
SLEPC-13	The tool should include an operational level energy analysis for all types of building, based on current legislation.	The assessment of the energy performance of the building with operational certification is a new field for the European member states. This work entails the documenting of current operational rating procedures in European member states.	DoA, T3.2	Compare the output of the operational energy analysis with those exported from corresponding commercial software.	Major
SLEPC-14	Representation of the actual energy performance of buildings within a BIM environment.	Focus as well on smart sensors and digital twin practices.	DoA, T4.3	Provide the outputs of the operational level energy analysis to the end users, through the BIM environment.	Major
SLEPC-15	The tool should be able to calculate the financial indicators, developed in T3.3.	Need to develop a module for the calculation of the Life Cycle Costing (LCC)-based indicators and integration into the new rating classification system of EPCs.	DoA, T3.3	Determine these values using the recent methodology and then compare them to the values provided by the SLEPC solution as a way of validating the requirements.	Critical
SLEPC-16	The platform should be able to perform an operational methodology for the building's complex scale, according to the developed procedure in T3.4.	Need to develop a module for calculating KPIs regarding the neighbouring buildings and systems and integrate outputs into SLEPC operational rating calculation methodology (T3.5) for building complexes.	DoA, T3.4	The new EPC must include assessments on a bigger scale (Building Complexes).	Major
SLEPC-17	The platform should be able to perform a new integrated operational rating methodology according to the developed procedure in T3.5.	Need to develop a module for SLEPC operational rating assessment based on IEQ scheme, energy, and nonenergy analysis, Life Cycle Assessment (LCA) and Levels(s).	DoA, T3.5	Creation of a new operational EPC for Building Units and Building Complexes.	Critical

Table 8: Web Platform related functional requirements - Building digitalization towards SLEPCs

ID	Description	Rational	Origin/ Source	Fit Criterion	Priority
SLEPC-18	Develop an interface for Digital Building logbooks.	Allow the integration of the building energy performance information in digital databases.	DoA, T4.4	The tool has to be an integrated classification system for buildings that considers additional building assessment methods related to its energy behaviour.	Critical
SLEPC-19	The platform should be able to manage all the static and dynamic data	To be able to exchange real-time data among the various SLEPC components.	DoA, T4.1	The system has to implement all the required processes to be	Critical

	received from various sources (through designated APIs).			able to transfer all the required data to the system's components.	
SLEPC-20	The platform should feature data processing functionalities (i.e., back-up, data restore procedures, cleansing, normalization etc.).	To be able to ensure a seamless and continuous data flow within the SLEPC system.	DoA, T4.2	Seamless and continuous data flows within the SLEPC system.	Critical
SLEPC-21	The platform should be able to provide role-based authorisation and encryption as well as pseudo-anonymisation.	To be able to preserve data/user security in the local IoT ecosystem.	DoA, T4.2	Ensure data/user security.	Major
SLEPC-22	The platform verifies the collected values and time series in terms of reliability, accuracy, and completeness.	Data need to be verified by a tool for the monitoring of the data quality of the collected information.	DoA, T4.2	Compare the SLEPC verification to the current verification techniques.	Major
SLEPC-23	The platform will provide a Building Dynamic Behaviour Monitoring System for modelling of the dynamic behaviour of the building.	The overall modelling has to be user-centric, since the "occupant", parameter is the most significant variable affecting the overall behaviour of the building.	DoA, T4.2	Provision of the optimal model for the dynamic building behaviour.	Major
SLEPC-27	The platform should support the interconnection to 3rd party applications.	Develop APIs to ensure interaction between tools as well as importing/exporting datasets.	DoA, T4.5	The platform should be used by multiple connections.	Critical
SLEPC-29	The platform must be able to detect inconsistencies and gaps in the input data to ensure data quality.	Need to develop a software module to detect inconsistencies and gaps in the input data.	DoA	Prevent inconsistent or missing data that lead to false results, calculation errors, or even the whole calculation failure.	Major
SLEPC-30	The platform should be able to read data from smart sensors in (near) real-time to derive the SLEPC operational rating of buildings on a regular basis or upon request.	It is necessary to create a user interface for reading and understanding operational data to determine the building's operational rating.	Proposal	The building's IoT sensors and meters should provide at least hourly data.	Critical

Table 9: Web Platform related functional requirements - Added value tools

ID	Description	Rational	Origin/ Source	Fit Criterion	Priority
SLEPC-32	It should be possible for users to build renovation scenarios and assess performance on the platform.	It is already a fundamental aspect of current tools and ought to be supported for the platform's new KPIs and features.	DoA, T5.2	The end-user must be allowed to change the building's characteristics and issue a new certificate.	Major
SLEPC-33	The tool should be able to perform	Need to develop a module for the comparison of design	DoA, T5.2	The system should help users to understand and	Major

	benchmarking and evaluation of the building's performance.	data with actual operational data and present the comparison in the form of different KPIs.		compare building characteristics.	
SLEPC-34	The development of the SLEPC visualization platform will relate to the IoT sensorial middleware.	Provision of meaningful information in spatio-temporal domain to the building owners and occupants, assisting them in making decisions related to the performance and the optimal operation of the building.	DoA, T5.3	The Platform will be capable of visualizing the heterogeneous SLEPC information.	Critical
SLEPC-35	AI-added values tools will be integrated into the platform providing analysis of building data.	Extraction of meaningful information related to building's behaviour and usage that can lead to behaviour changes towards improving the energy performance of the building.	DoA, T5.1	Comparison of tools' outputs with pilot data.	Critical

Table 10: Not categorized functional requirements

ID	Description	Rational	Origin/ Source	Fit Criterion	Priority
SLEPC-36	The platform provides users with information on the actual operational performance of their facilities.	It is necessary to give users a real-time depiction of the building's energy use.	Proposal	Users should be able to monitor the (near) real-time operation performance of their building.	Major
SLEPC-37	SLEPC solution should notify the appropriate public authorities, in order to execute penalty measures for excessive building consumption or incentive processes for underconsumption.	It is necessary to implement incentives and restrictions to increase user engagement and awareness of a building's energy efficiency.	D1.1	Deviations should be accessible via an API to third-party platforms.	Nice to have
SLEPC-38	The platform's update can be related to the user's information on new systems and technologies.	The EPCs should be updated with reference to new technologies that are currently available on the market.	D1.1	Compare the output of the SLEPC solution to the input values for the technologies of the chosen commercial software.	Nice to have
SLEPC-39	Users will be able to provide feedback after manually reviewing data, processes, etc.	The operational data should be accessible to be manually checked by users to ensure their accuracy. They ought to be able to configure the system or make other changes if the requirements are not met.	D1.1	The user will be able to analyze the building's data through graphical representation and manually request additional verification of the data's veracity.	Nice to have

SLEPC-40	Unification of end energy data into primary energy.	To allow for an accurate comparison of CO2, the end energy demand is transformed into the primary energy demand.	D1.1	The monthly cogeneration practice in the region shall be considered in the conversion factors.	Major
SLEPC-43	The platform should be able to export reports and EPCs according to the new SLEPC asset and operational rating.	Need to develop an interface to generate documents.	D1.1	The User should be able to receive a finalized document after performing any assessment. This document may be used as evidence of the buildings' performance.	Mediu m

Table 11: Web Platform related non - functional requirements

ID	Requirement Type	Description	Rational	Origin/ Source	Fit Criterion	Priority
SLEPC-45	Interoperability	Need to use specific data formats and communication protocols to facilitate interoperability among the SLEPC components.	The platform should be able to share information among SLEPC components.	Proposal	Validation of the solution through a questionnaire to the stakeholders and experts' reviews.	Critical
SLEPC-46	Performance	The platform must provide quick responses (request and data processing) to the users' actions and/or to the other SLEPC components.	Need to avoid time-consuming processes in order to minimize delays and maintain thus the optimal operation of the SLEPC components.	Proposal	Validation of the solution through a questionnaire to the stakeholders and experts' reviews.	Major
SLEPC-47	Scalability	The platform must be able to accommodate a wide range of simultaneous requests.	Needs to perform "as expected" even at the highest workloads.	Proposal	Validation throughout the pilot phase.	Major
SLEPC-49	Accessibility	The platform should implement an accessibility function for users with disabilities.	Need for access by all users.	Proposal	Validation of the solution from users with disabilities and providing relevant feedback.	Nice to have
SLEPC-50	Scalability	The platform must be compliant with the latest EPBD revisions, EU standards, and calculation schemes.	A joint platform for EU MS for both rating systems is required by the EC.	Proposal	The provision of asset and operating ratings.	Major
SLEPC-51	Scalability	The SmartLingEPC platform should be	Needs information as regards the reference		Test the solution on	Minor

		able to certify any building located within the EU countries involved in the project.	building climatic conditions etc., for all EU countries.		case studies located in different EU countries	
SLEPC-52	Accessibility	The platform should have instructions at every step of the process.	Need to make the prosses more comprehensive.	Proposal	Validation of the solution through a questionnaire to the end-user (neighbours participating in an energy community).	Medium
SLEPC-53	Accessibility	The end user should have a high level of flexibility to parametrize the building model and insert information related to their needs and preferences.	The user should be able to check on the metered data, and for quality measurements and make alterations based on the actual manually measured data.	Proposal	Validation of the solution through a questionnaire to the stakeholders and experts' reviews.	Major
SLEPC-54	Accessibility	The platform should provide a stepwise certification procedure where the assessor can access any calculation stage.	Need for the user to go back a few steps of any prosses and alter information, even when the resulting EPC is issued, due to uncertainties. (This will not make a new EPC).	Proposal	Validation of the solution at the pilot sites.	Medium
SLEPC-55	Usability	The language used in the platform should be simplified in order for the user's understanding to be facilitated.	The understanding of SmarLivingEPC System from non-technical people.	D1.1	Validation of the solution at the pilot sites.	Medium
SLEPC-56	Usability	The platform's primary language should be English and translated into other EU languages.	Increase the platform's usability in different EU countries.	D1.1	Validation of the solution at the pilot sites.	Nice to have

5.2 Platform Architecture

Figure 31 illustrates the Smart Living EPC Web Platform architecture. All the relevant services provided by the platform are grouped under the main software *Backend*, either as software packages that are locally installed or as external services. The software stack has been developed using Python 3 programming language and a number of available open-source libraries in order to implement several necessary features. The latter include:

- Flask[4], which has been used to design the various API routes that correspond to platform functionalities. It is a micro web flexible framework that provides customizable functionality to the developer through extensions. Available extensions support form validation, upload handling, object-relational mapping, several authentication technologies and other framework tools.
- SQLAlchemy[5], an open-source SQL toolkit and object-relational mapper (ORM), which has been used to link the backend with the D^2EPC Repository.
- Marshmallow[6], an Object–relational mapping (ORM)/ Object Document Mapper (ODM)/framework-agnostic library for converting complex datatypes, such as objects, to and from native Python datatypes. The package has been used for developing the validation features of the Web Platform.
- Pandas[7], a data analysis and manipulation tool, which has been used for data structuring and post-processing

Additionally, the *Web Platform Database* serves as a common storage location for user input data (personal information, calculation parameters etc.), configuration parameters and service outputs. It is based on PostgreSQL[8], which is an open-source Database Management System (DBMS). On the other hand, the *CIEM Database* acts a data repository for BIM files and real-time data collected from the onsite building monitoring infrastructure.

The software *Frontend* is the main presentation layer of the Smart Living EPC solution and features all the designed user interfaces. They are grouped into three platforms:

- The Digital Twin Platform, hosted by IES.
- The CIEM Platform, hosted by QUE.
- The main Smart Living EPC Web Platform, hosted by CERTH, which will also enable user redirection to the two aforementioned platforms.

The user interfaces of the Smart Living EPC Web platform have been implemented with the Angular[9] web development framework and are described in the following section. Additional information regarding the other two platforms will be documented in the next version of this deliverable.

[4] https://flask.palletsprojects.com/en/2.3.x/

[5] https://www.sqlalchemy.org/

[6] https://marshmallow.readthedocs.io/en/stable/

[7] https://pandas.pydata.org/

[8] https://www.postgresql.org/

[9] https://angular.io/

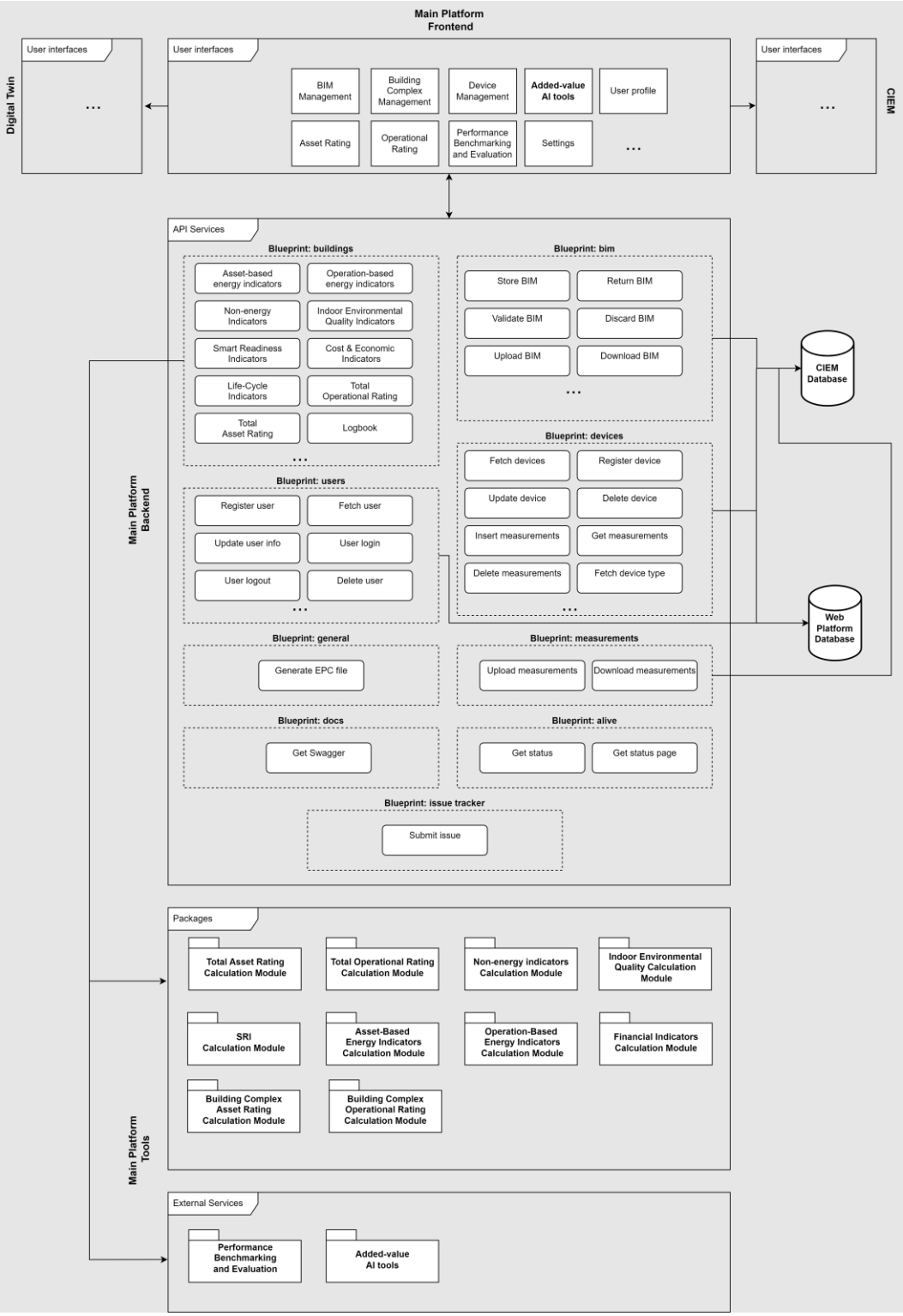


Figure 31: Web Platform Architecture

5.3 User Interfaces

The following sections describe the various user interfaces of the Web Platform that have been designed up to the current version of this deliverable.

5.3.1 Welcome page

The initial access to the platform takes the user to the registration/login page (Figure 32 and Figure 33). This interface allows inserting the necessary information in order to create a new account in the Web Platform. Upon administrator approval, the user receives a confirmation email and is then eligible to log into the platform. In case of a missing password, an email can be sent using the corresponding recovery page (Figure 34) to enable the password reset.

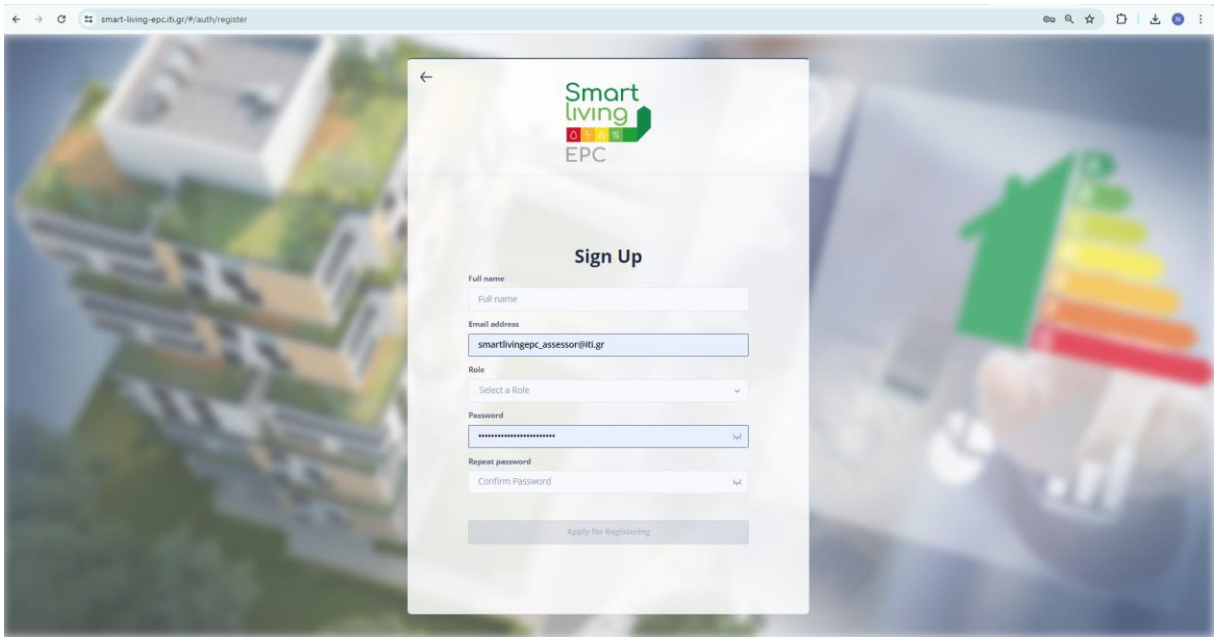


Figure 32: Registration page

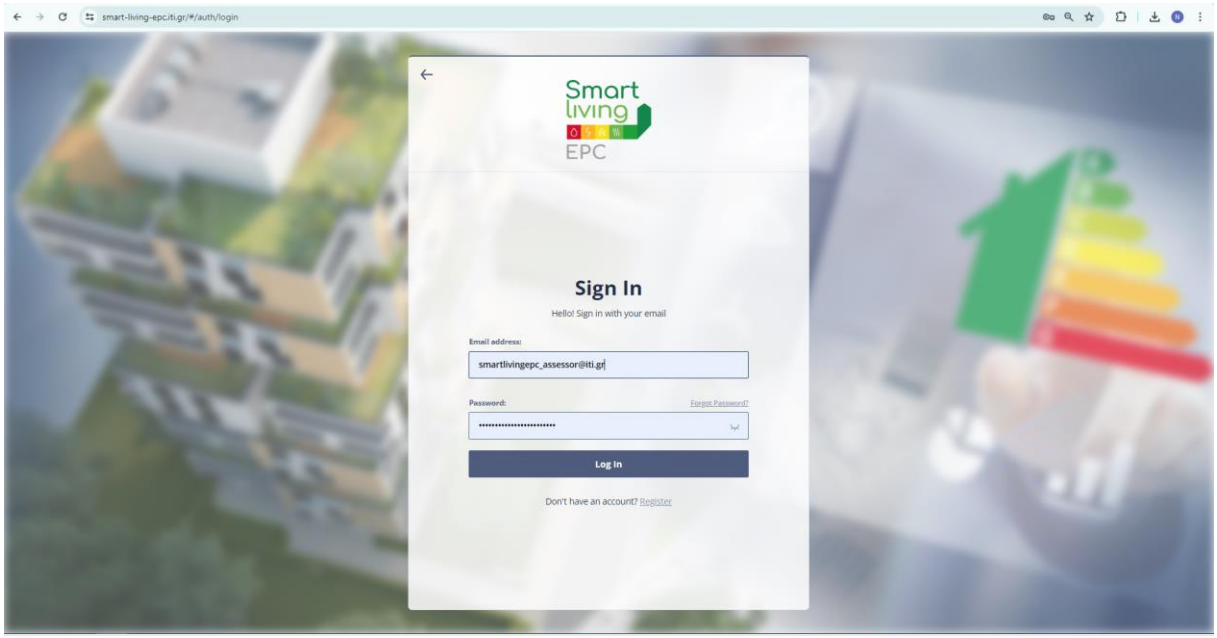


Figure 33: Login page

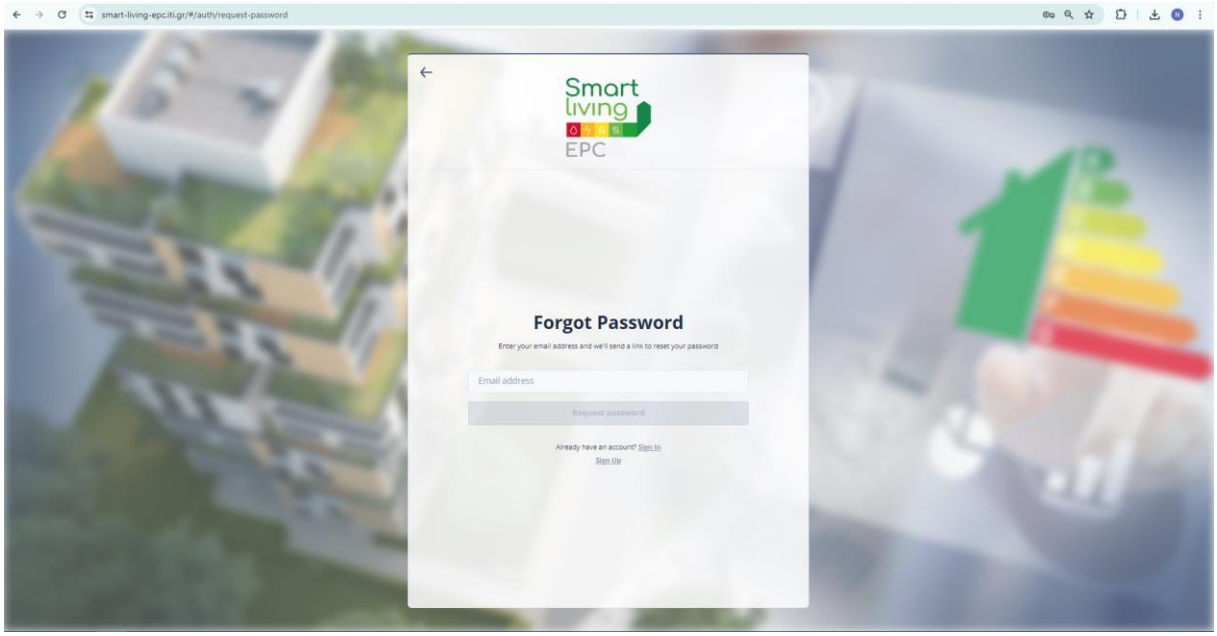


Figure 34: Password recovery page

Even after successful registration and first-time login, the user is required to take an additional security step and verify the email address that was used in the registration, otherwise several features of the platform will not be available (Figure 35).

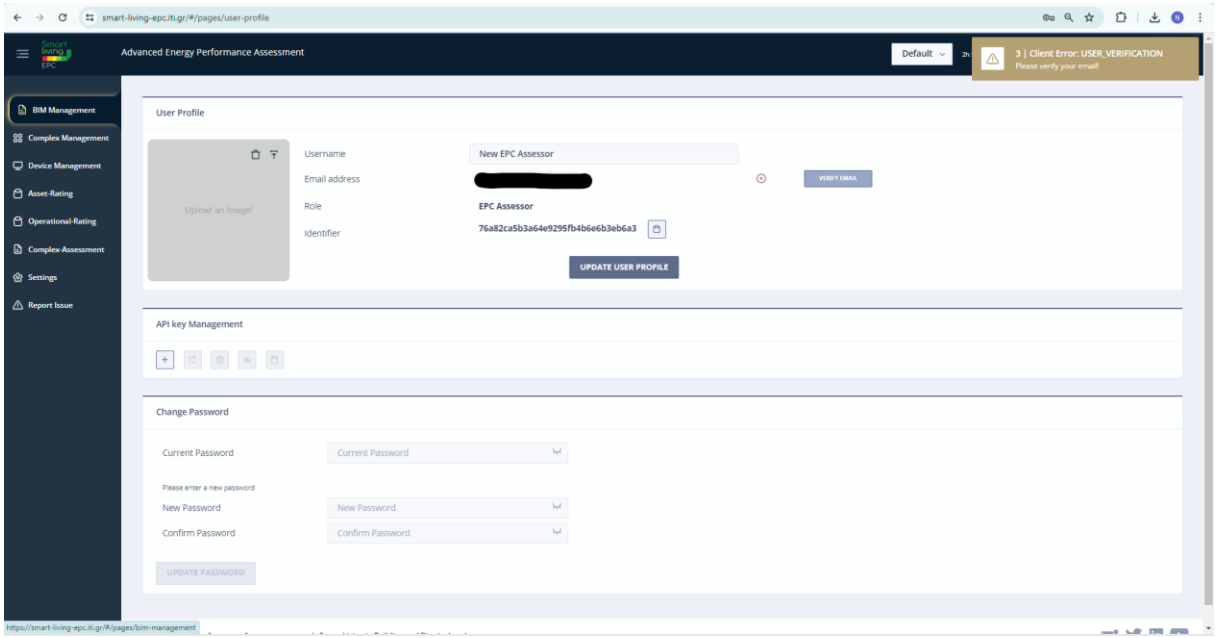


Figure 35 Non-verified user platform access

The user eligibility to perform various actions within the Smart Living EPC Web Platform depends on their role, which is selected during the registration process. The main role corresponds to the *EPC Assessor*, who is able to perform all the actions related to building performance assessment. These include:

- The upload, validation and management of BIM files
- The creation and management of building complexes
- The registration and setup of new monitoring devices
- The setup and calculation of the asset and operational ratings for buildings and building complexes

A *Building Tenant* user, on the other side, is able to view created building units/complexes as well as assessment results within the platform, though they cannot perform any of the aforementioned modifications or create new elements.

An *Authority* user role has also been defined, which corresponds to groups with elevated viewing rights over the entire building stock of the Web Platform, e.g. within a region or a country. Essentially, such a role can be described as a Building Tenant with access to multiple buildings, as in this case, no editing rights are provided as well.

Finally, a fourth user role has been determined and concerns the overall system's administration, which allows full access to all the uploaded building performance data as well as for user management capabilities.

5.3.2 Main dashboard & user profile pages

The first page where the user is redirected after login is depicted in Figure 36. This includes a navigation pane, which is active in all interfaces of the Web Platform and allows to access the various services of the Web Platform. A menu option on the top right corner of this page leads to the Profile page (Figure 37). Herein, the user is able to modify their credentials, change their display name, upload a profile picture and retrieve their unique user identification number, which can be provided to other users in order for them to enable viewing/editing rights on building entries that have not been uploaded by the user. Additionally, this page features an API key management interface, which gives the ability to create/revoke a personalized API key for accessing various

platform services directly. This can be utilized by user third-party applications that require the execution and retrieval of assessment results.

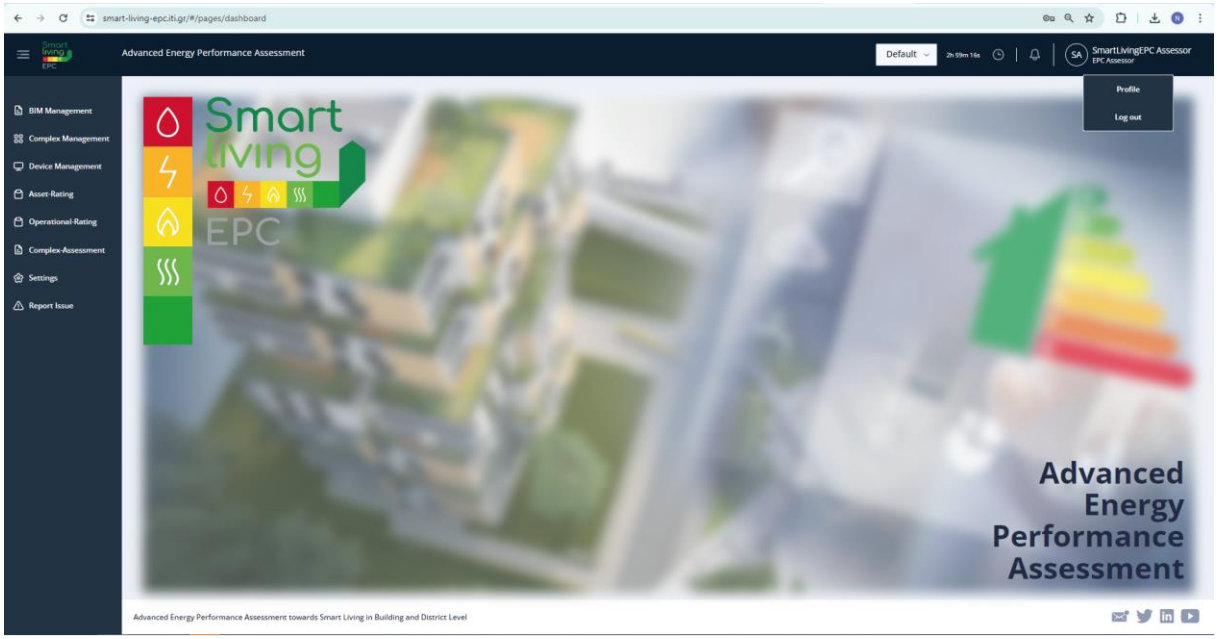


Figure 36: Landing page

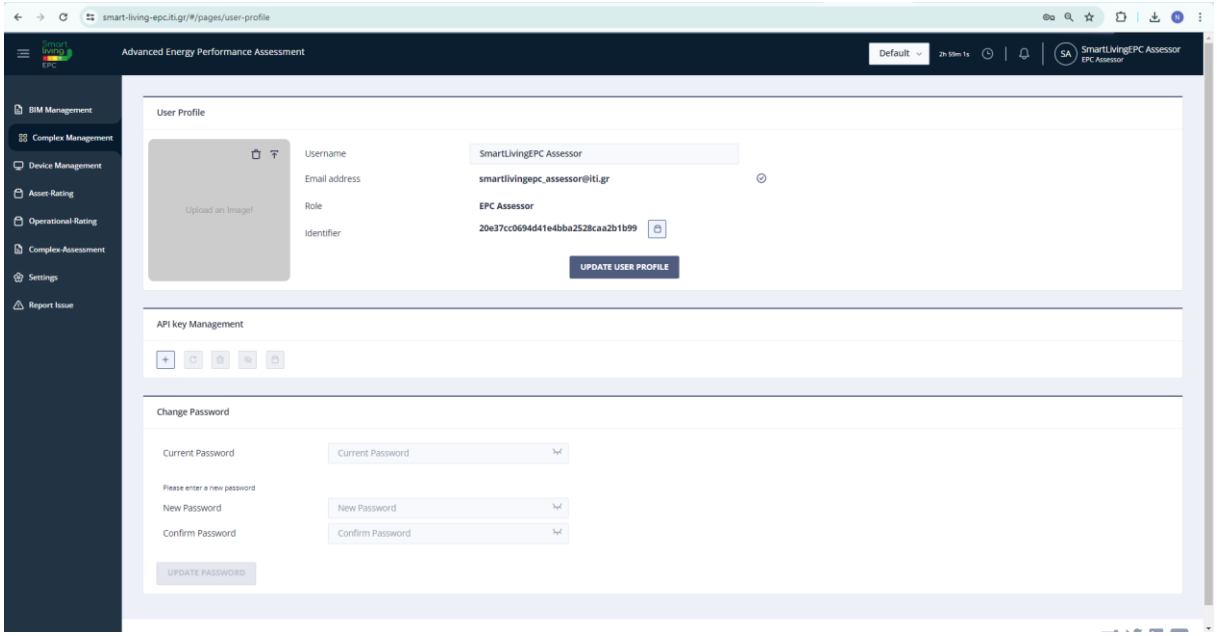


Figure 37: User profile page

5.3.3 BIM Management page

This page (Figure 38) allows the upload, preliminary validation and management of BIM files, which initiate the EPC assessment procedure. The validation process ensures that the files uploaded (in .ifc format) are compliant with a set of minimum design requirements, informing the user with an error message in the opposite case.

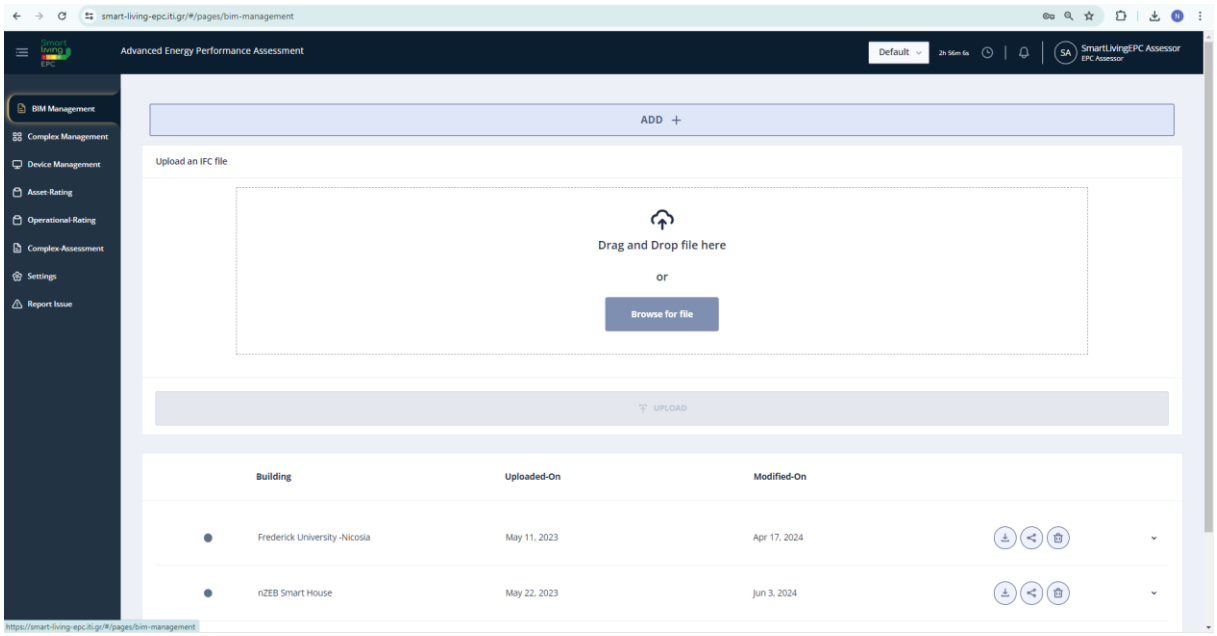


Figure 38: BIM management page - upload file

The file is then transmitted to the CIEM Database for storage, while a number of options become available within the page (Figure 39).

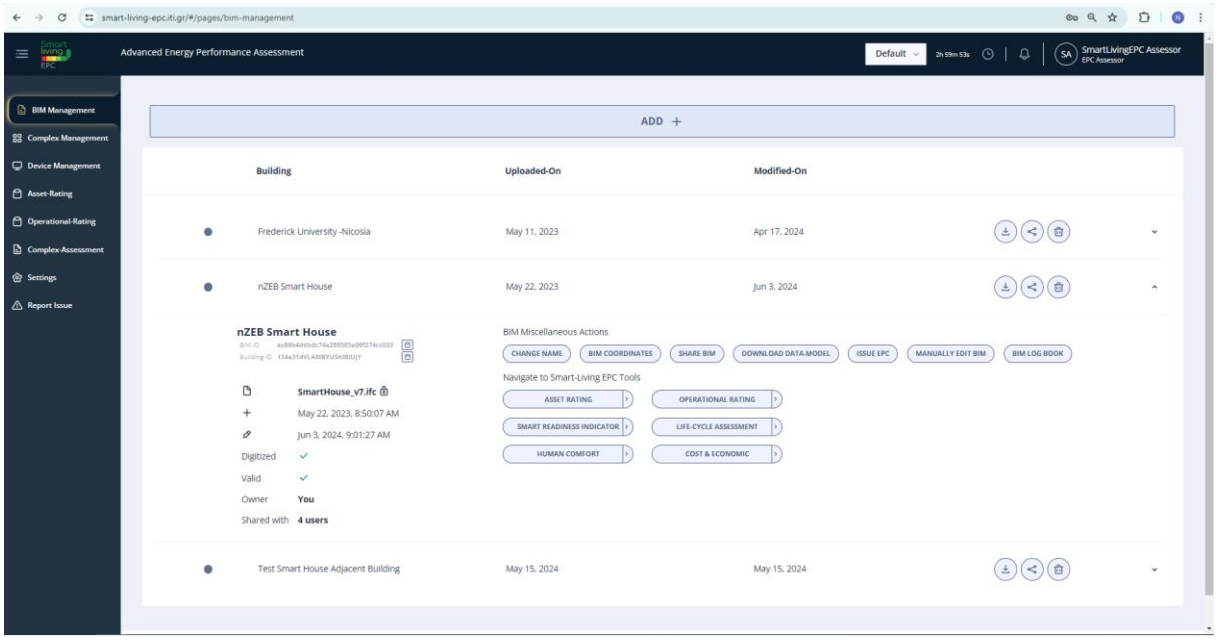


Figure 39: BIM management page - BIM functionalities

The user is able to change the appearing building name, as well as, its location, providing either the building address or latitude-longitude explicit coordinates (Figure 40).

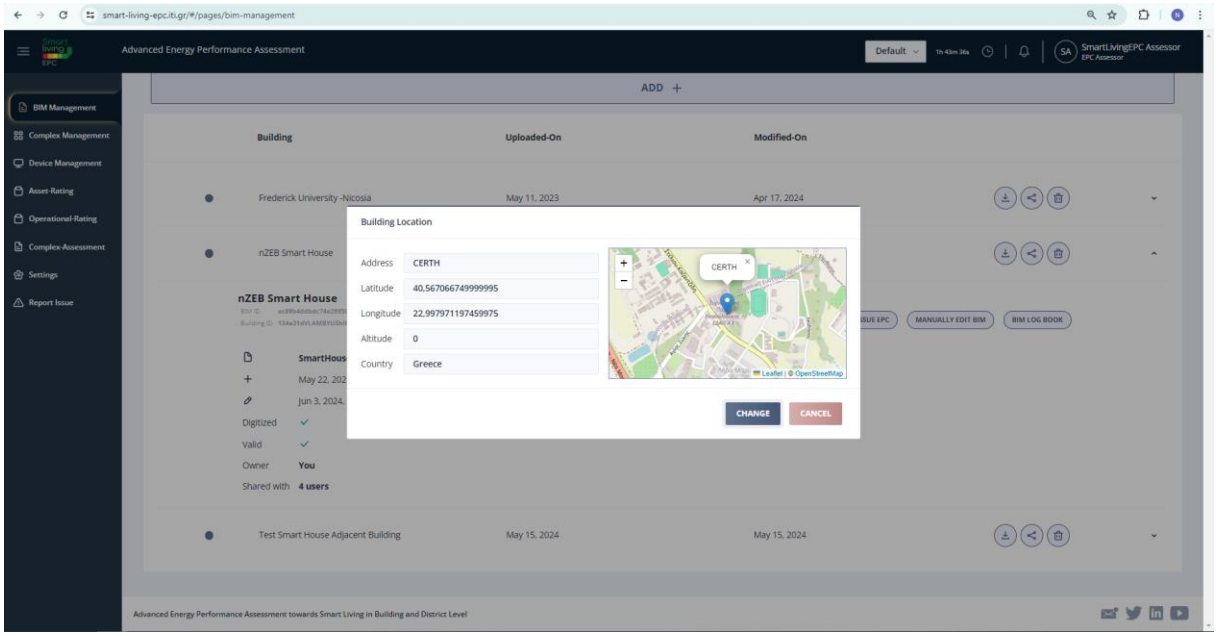


Figure 40: BIM management page - building coordinates setup

The BIM file can also be shared with other users, who, based on their role, can either view or perform modifications on it. This is enabled through the "Edit BIM" option, which essentially loads the file in a user-friendly representation (Figure 41) and providing editable parameter fields that can be changed, accordingly. The main application of this feature is the integration of results of building energy audits (described in the deliverable D2.4 *Asset methodology assessment in building level v2*. As an example, a new assessed efficiency value for a heating system can be directly updated within the building entry and taken into consideration in the calculation of asset-based energy indicators.

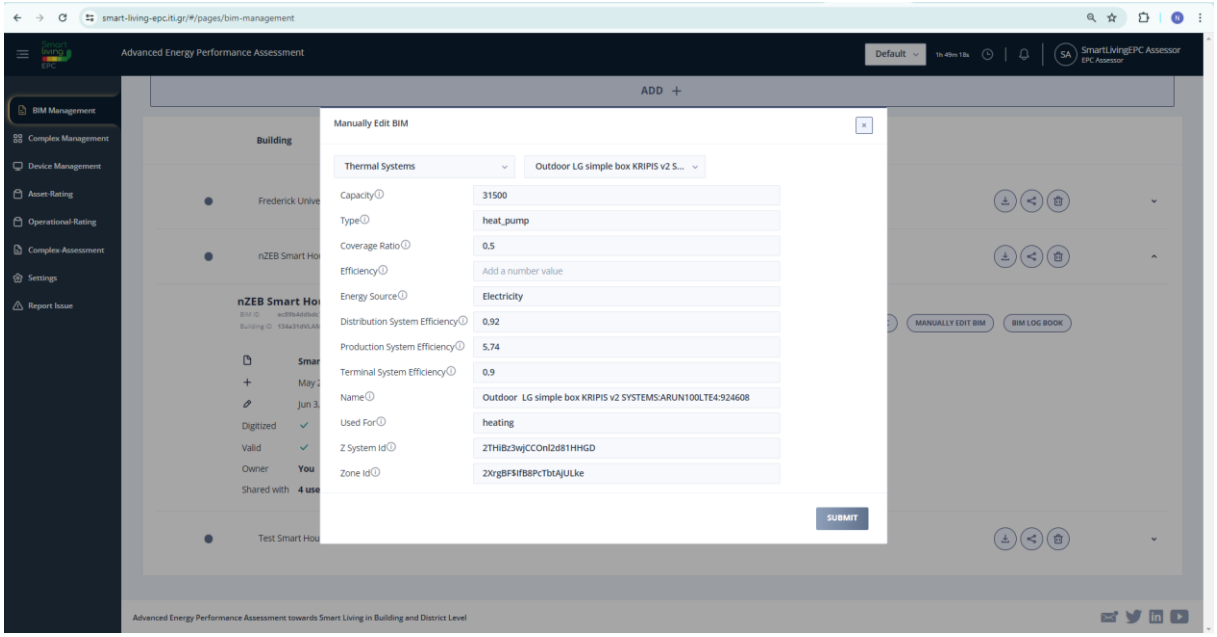


Figure 41: BIM management page - file edit

Finally, the BIM Management page provides access to the Building Logbook Figure 42, which describes the entire building history, starting from the first upload and until the its current state. It includes all the detailed changes that have been applied to the building through the abovementioned functionalities, along with the asset-based and operation-based EPC results that correspond to each revision.

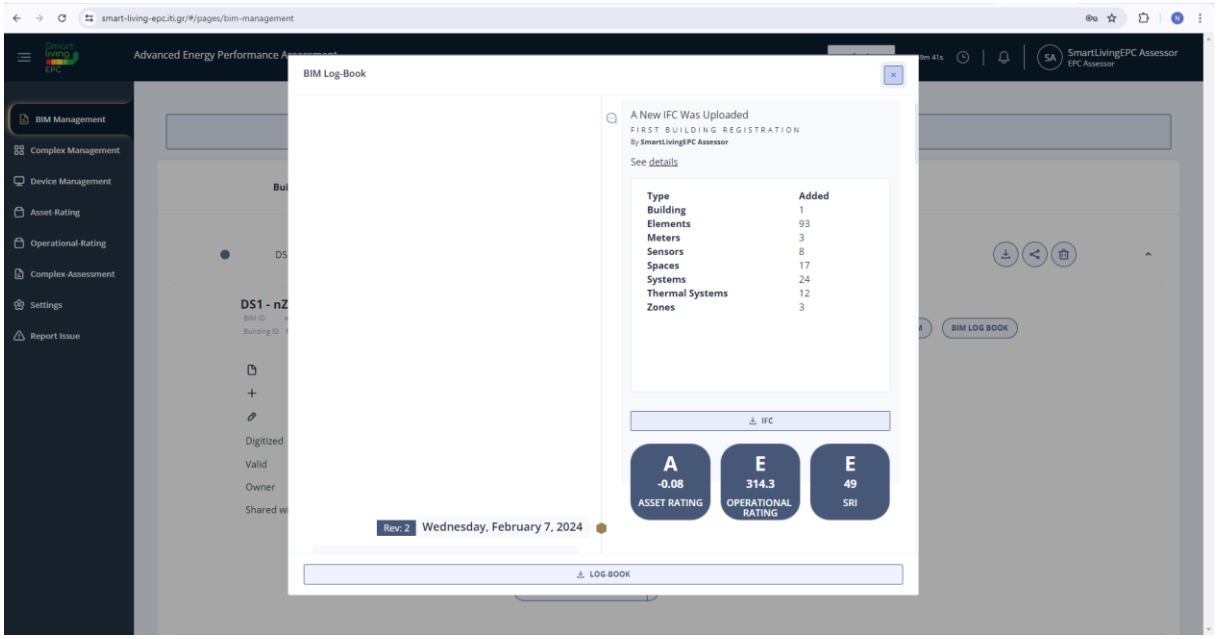


Figure 42 BIM Management page - Building Logbook

5.3.4 Building Complex Management page

Buildings that have been registered into the Smart Living EPC Web Platform, as described in Section 5.3.3, can be organized as building complexes via this page Figure 43. Herein, the user can select a registered building to act as the complex formation basis and then add nearby buildings within a predetermined radial area, as depicted in Figure 44. Upon successful setup, the new building complex can then be shared with other users, without the need to provide separate access to the BIM files of the consisting buildings. A dedicated button then leads to the Complex Assessment page.

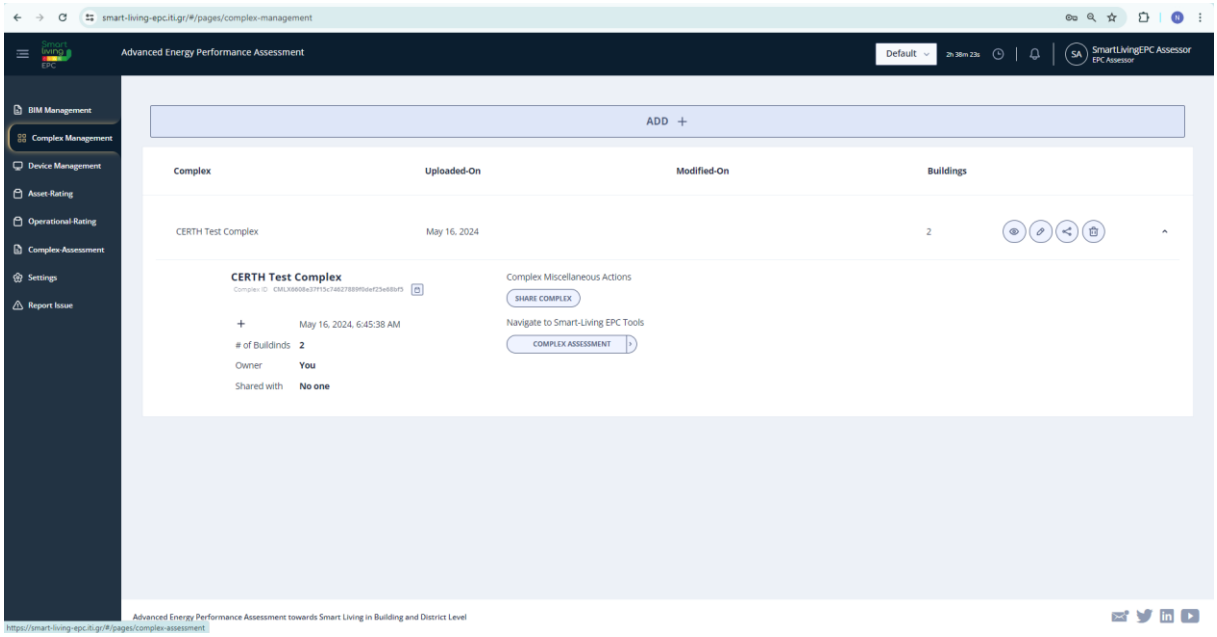


Figure 43: Complex management page - list of building complexes

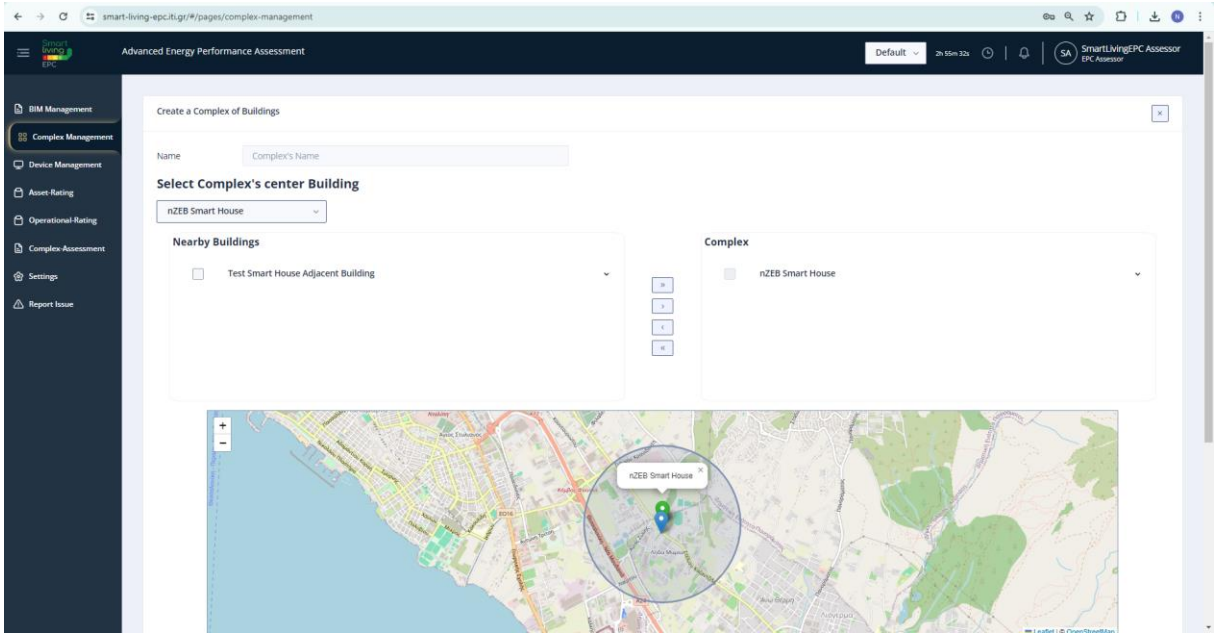


Figure 44: Complex management page - building complex setup

5.3.5 Device Management page

The building monitoring devices that are extracted from the BIM file as well as new registered devices can be managed within this page (Figure 45).

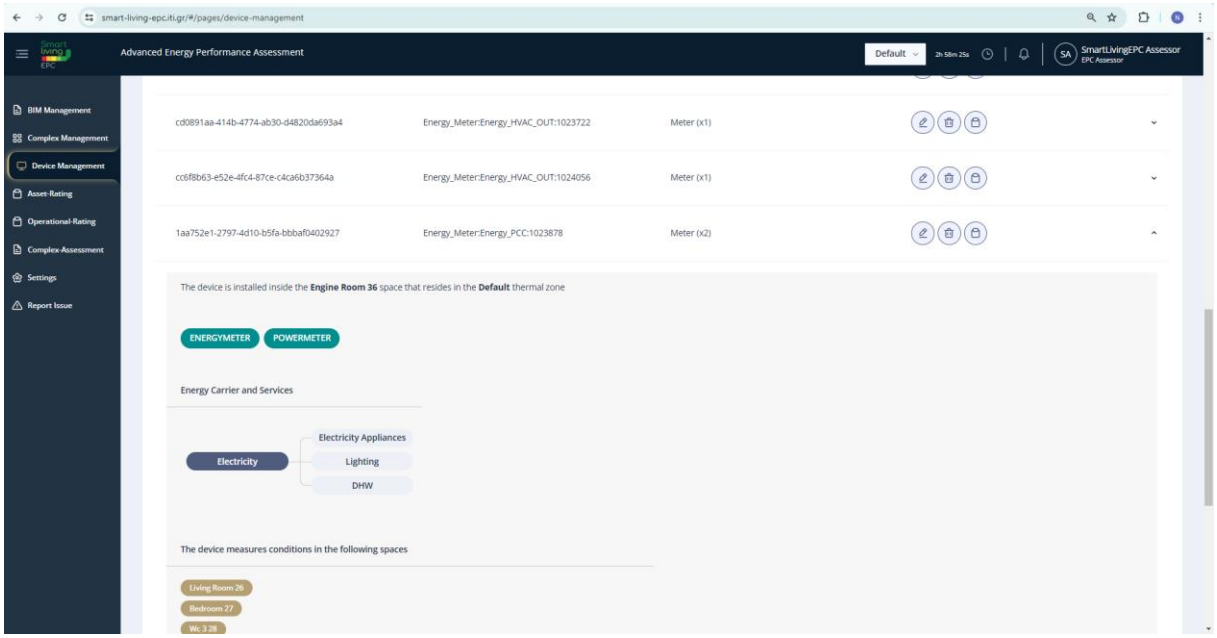
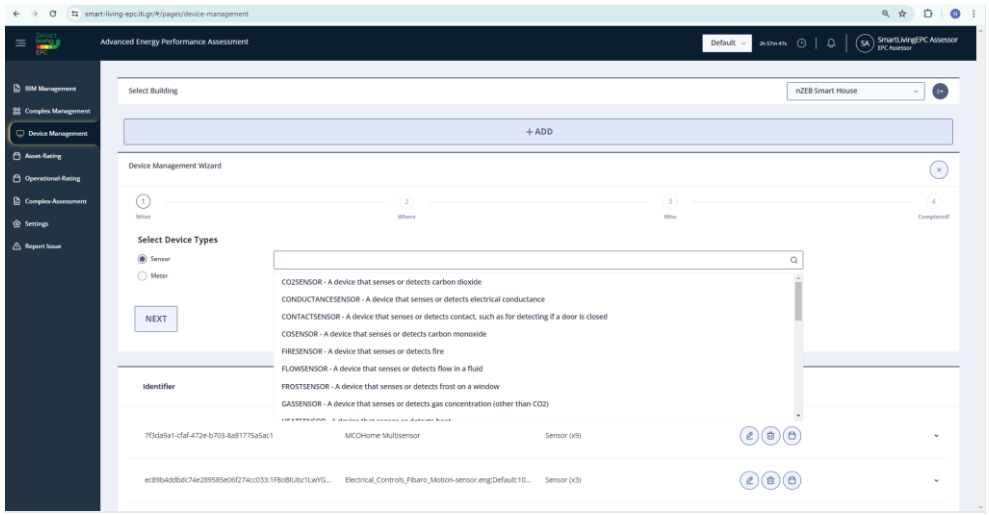


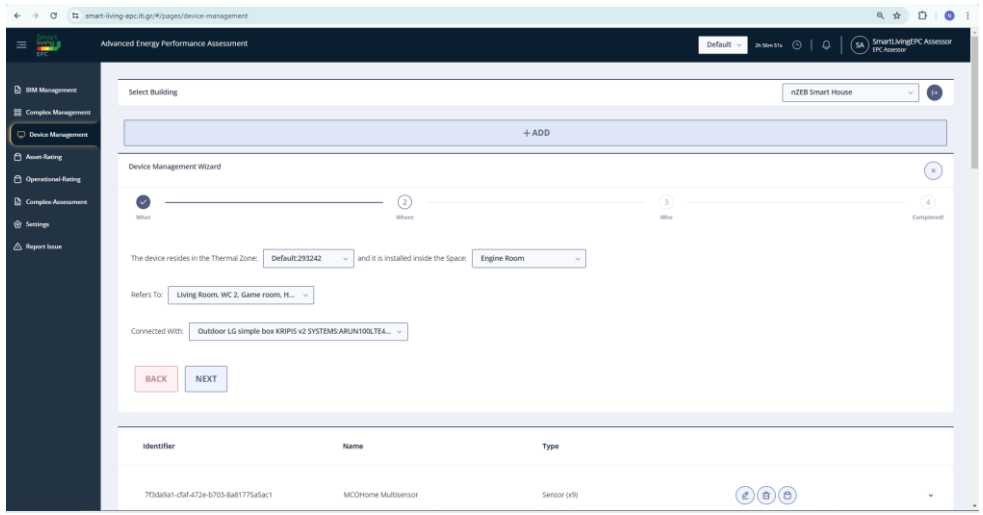
Figure 45: Device Management page

A step process is required in order to edit/register a new device as following:

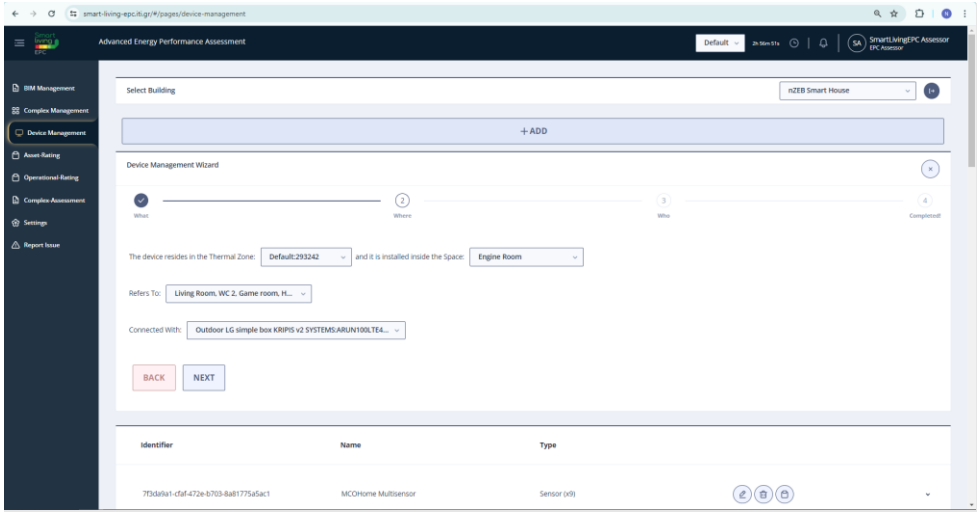
1. Configuration of the device type (sensor/meter) and, for metering devices, definition of monitored energy carrier and energy uses (Figure 46-i)
2. Allocation of the device in a thermal zone and space of the building and, for metering devices, semantic linking to monitored spaces and building systems (Figure 46-ii)
3. Assignment of name and unique device ID, with the latter used to match the static representation of the device in the building instance with real-time measurements provided by the CIEM (Figure 46-iii)



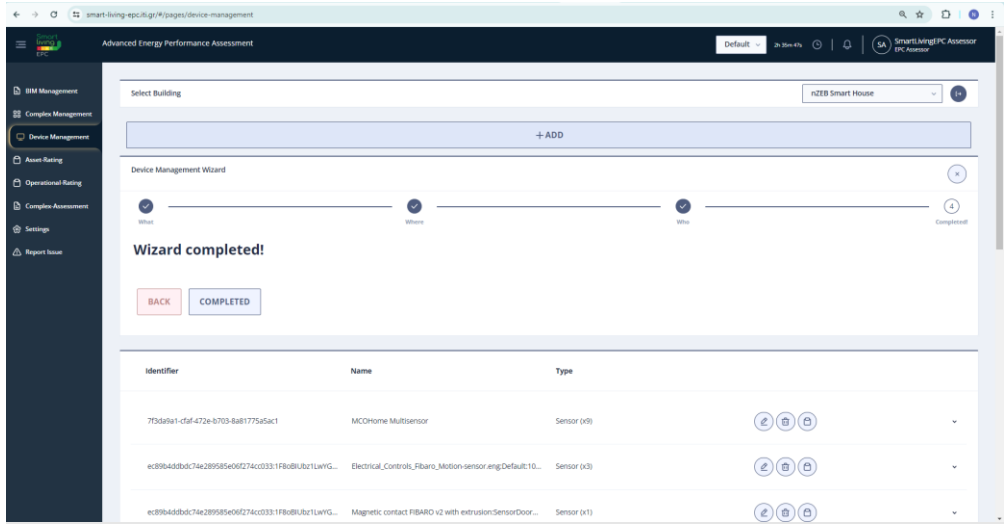
i)



ii)



iii)



iv)

Figure 46: Device management page - registration process

5.3.6 Asset Rating page

5.3.6.1 Energy indicators tab

The building energy assessment using its as-designed energy data can be carried out in this tab. The relevant information that has been extracted from the BIM file, as described in section 5.3.3, is loaded and validated against missing parameters. In such an event, a user input form is provided (Figure 47), indicating the required data to be filled in by the assessor. If the inserted information is processed successfully, the asset-based energy indicators are displayed, as in Figure 48. These include final and primary energy figures, as well as comparison between the renewable and non-renewable primary energy parts, both on a monthly scale as well as totals per energy service and energy carrier.

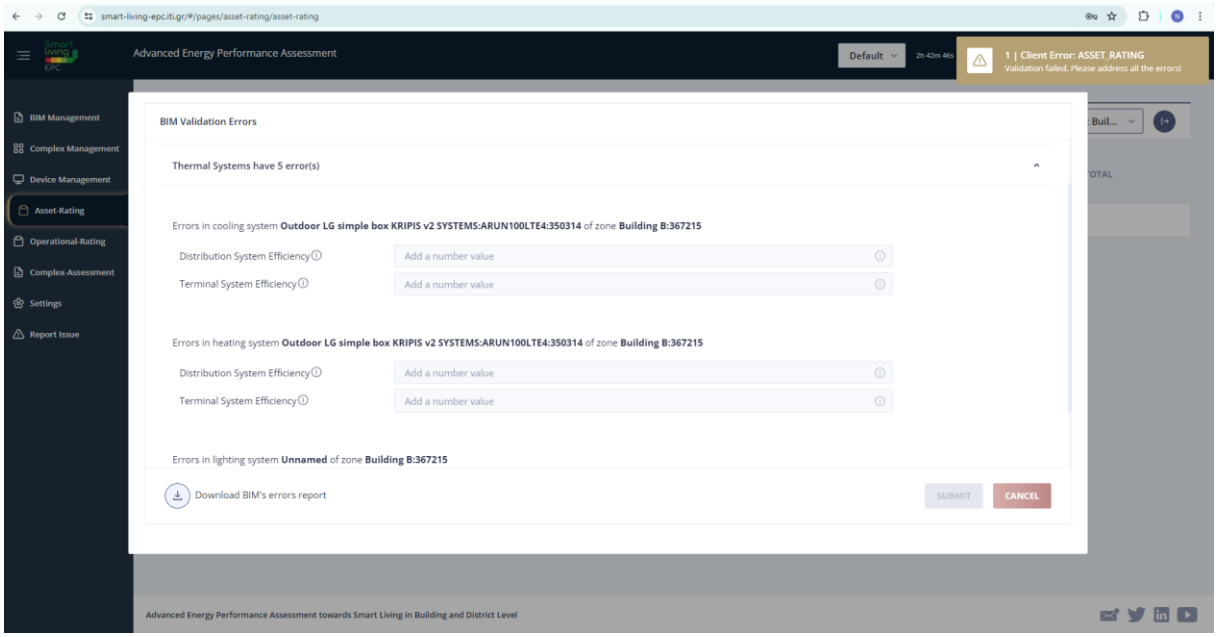


Figure 47: Energy tab - validation

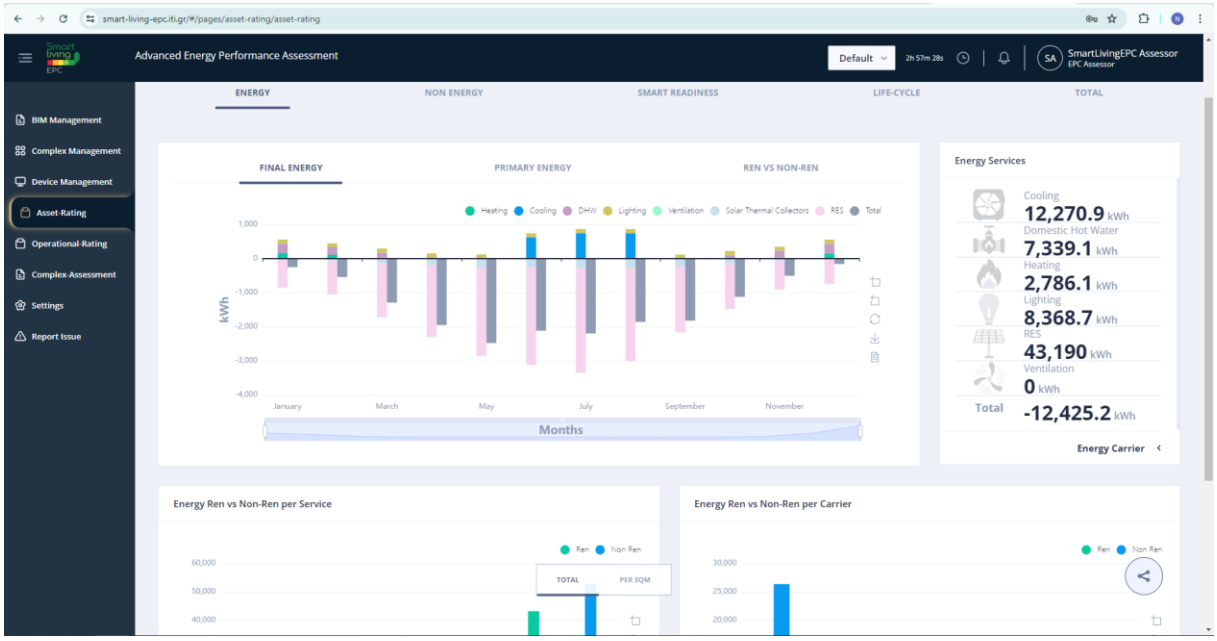


Figure 48: Energy tab - asset energy indicators results

5.3.6.2 Non-energy indicators tab

This tab undertakes the setup and calculation of the non-energy indicators. They are divided in four distinct subcategories i.e. acoustic comfort, thermal comfort, visual comfort and indoor air quality. For each category, the user should first configure assessment zones, which are created by selecting several building spaces and providing all the necessary calculation parameters. Inputs related to the zone geometry, i.e. area, volume, window area etc. are automatically determined based on the BIM information. Figure 49 depicts the setup of an acoustic assessment zone while for other non-energy indicators the process is similar.

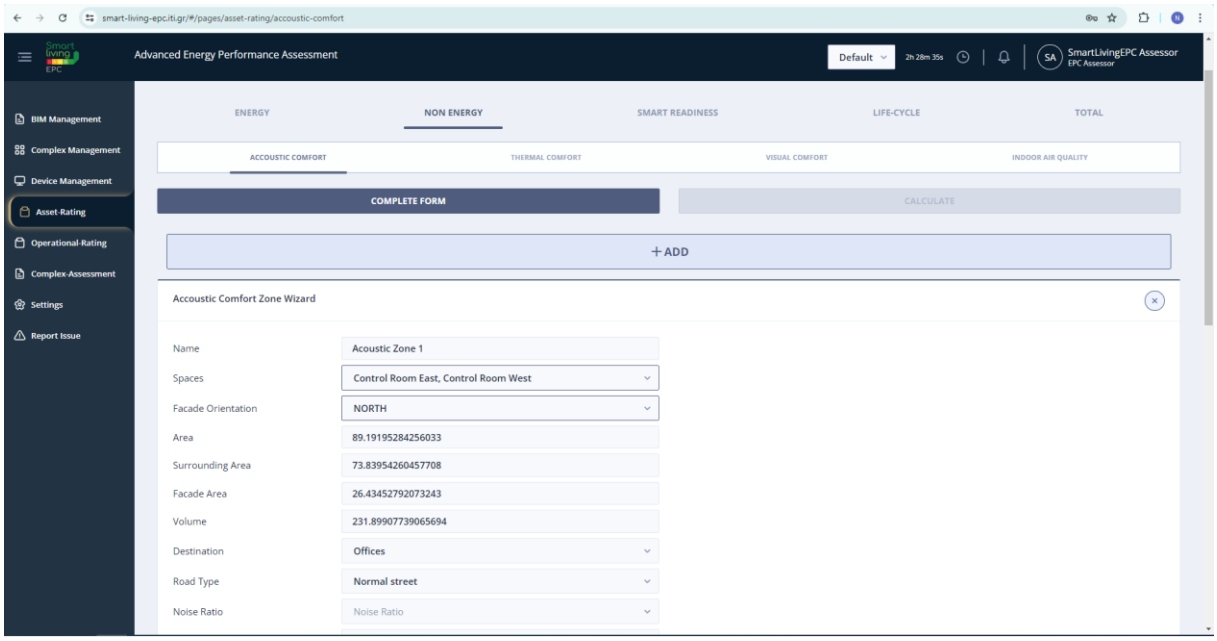


Figure 49: Non-energy tab - acoustic comfort zone setup

Acoustic comfort

The acoustic comfort assessment results for Demo Site (DS)1 are displayed in Figure 50. They include the total building acoustic comfort compliance and results per assessment zone (target dbA, target reverberation, target frequency compliances).

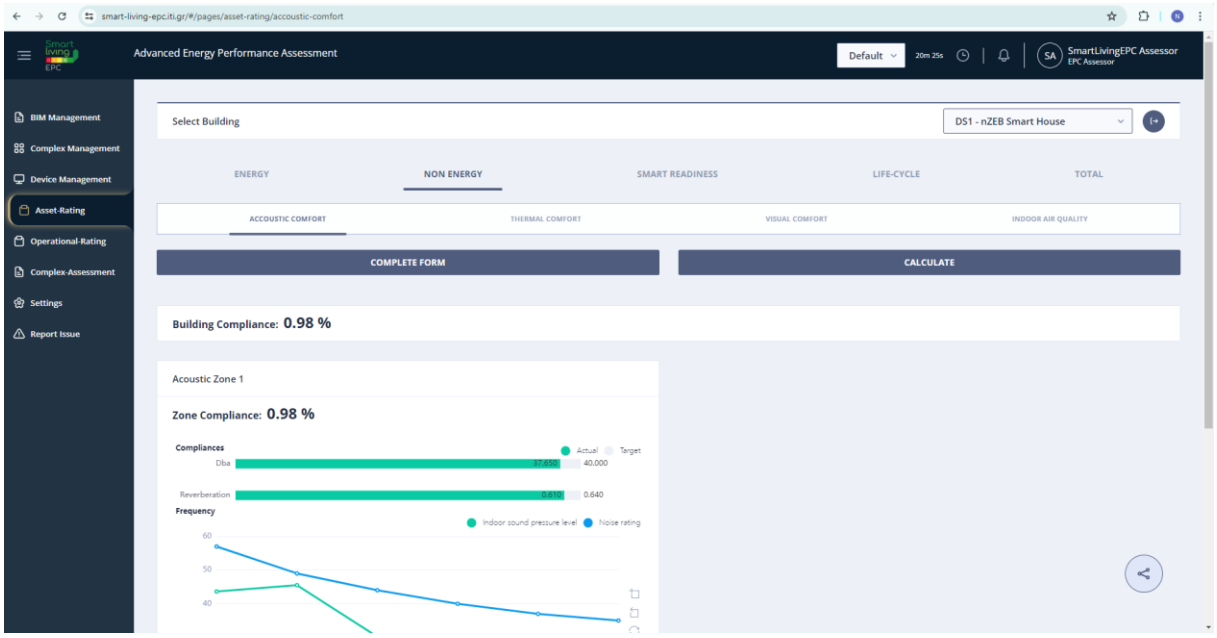


Figure 50: Non-energy tab - acoustic comfort indicators

Thermal Comfort

The thermal comfort assessment results for DS1 are displayed in Figure 51. They include the total building thermal comfort score, as well as results per thermal assessment zone (mean radiant temperature, predicted mean vote, predicted percentage of dissatisfied, relative humidity).

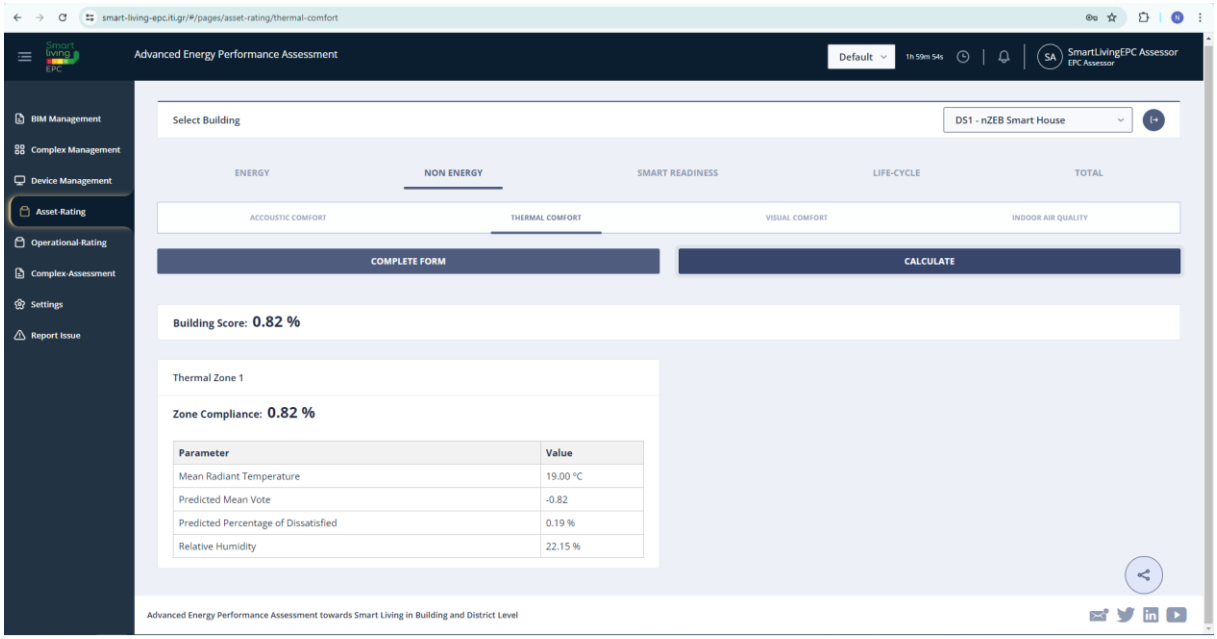


Figure 51: Non-energy tab - thermal comfort indicators

Visual Comfort

The visual comfort assessment results for DS1 are displayed in Figure 52. They include the total building visual comfort score, as well as results per visual assessment zone (daylight, illuminance, luminaire colour rendering and luminaire temperature scores).

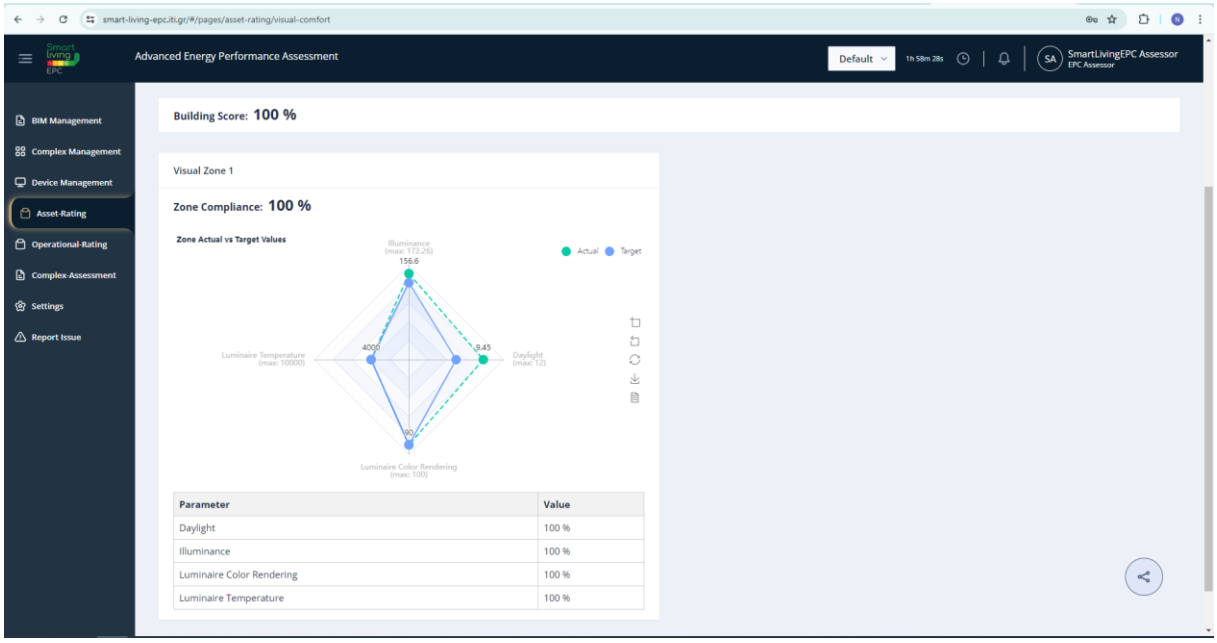


Figure 52: Non-energy tab - visual comfort indicators

Indoor Air Quality

The indoor air quality assessment results for DS1 are displayed in Figure 53. They include the total building IAQ compliance, as well as the average CO_2 per assessment zone.

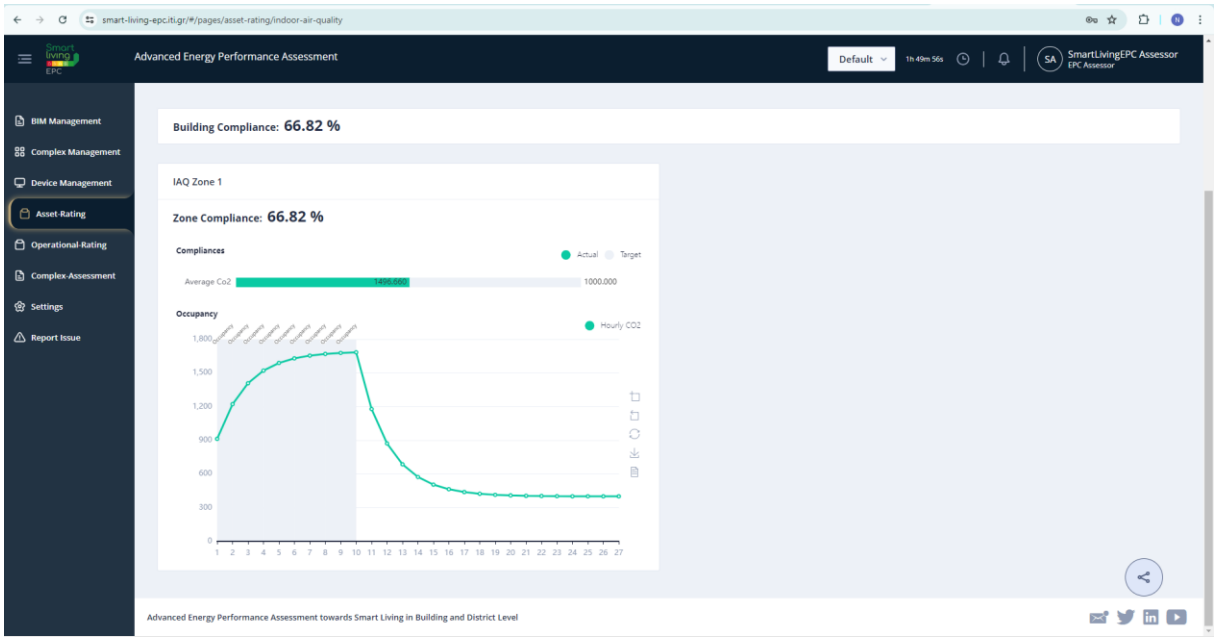


Figure 53: Non-energy tab - indoor air quality indicators

5.3.6.3 Smart Readiness tab

Within this page, the user can perform a building SRI assessment, aided by extracted BIM data. Upon filling some basic personal information (Figure 54), the initial building characteristics (Figure 55) must be provided. However, several parameters are automatically inserted (e.g. building type/use, useful area etc.), as they are parsed from the building's BIM file. The final step requires the setup of the smart domains of the building and their corresponding smart services and functionality levels (Figure 56). As previously, the effective parsing of the BIM file allows the automatic identification of the presence of several domains and services, as well as of indicative functionality levels, which are pre-filled in the input forms. The user may correct any value based on their actual building audit that has been carried out.

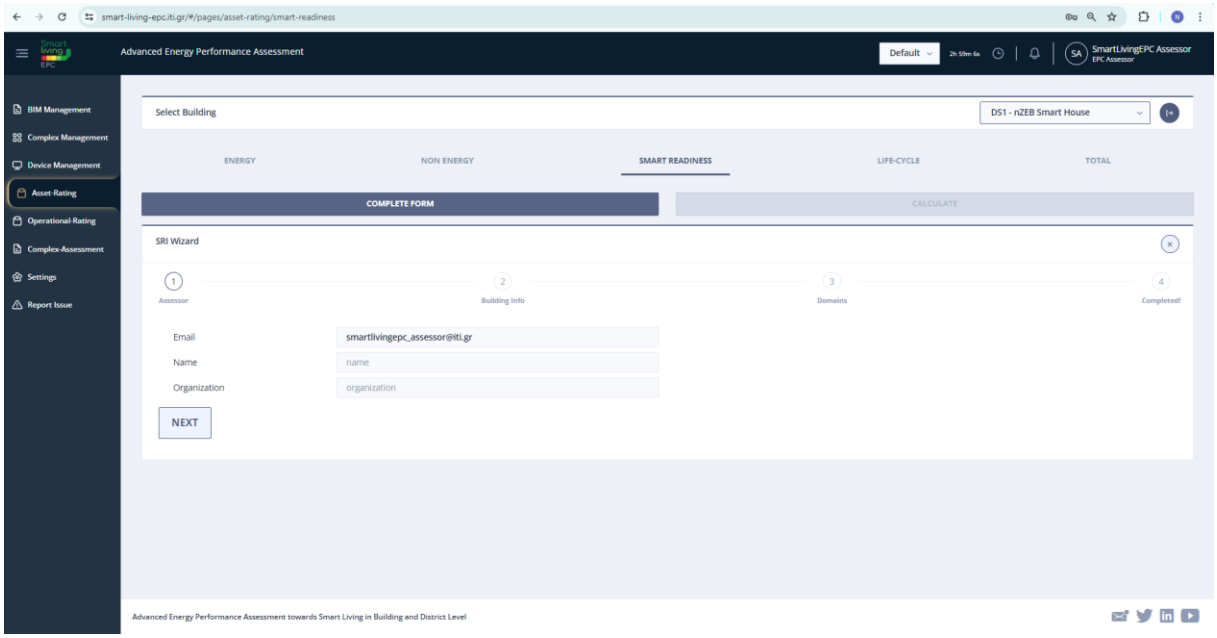


Figure 54: Smart Readiness tab - personal information input

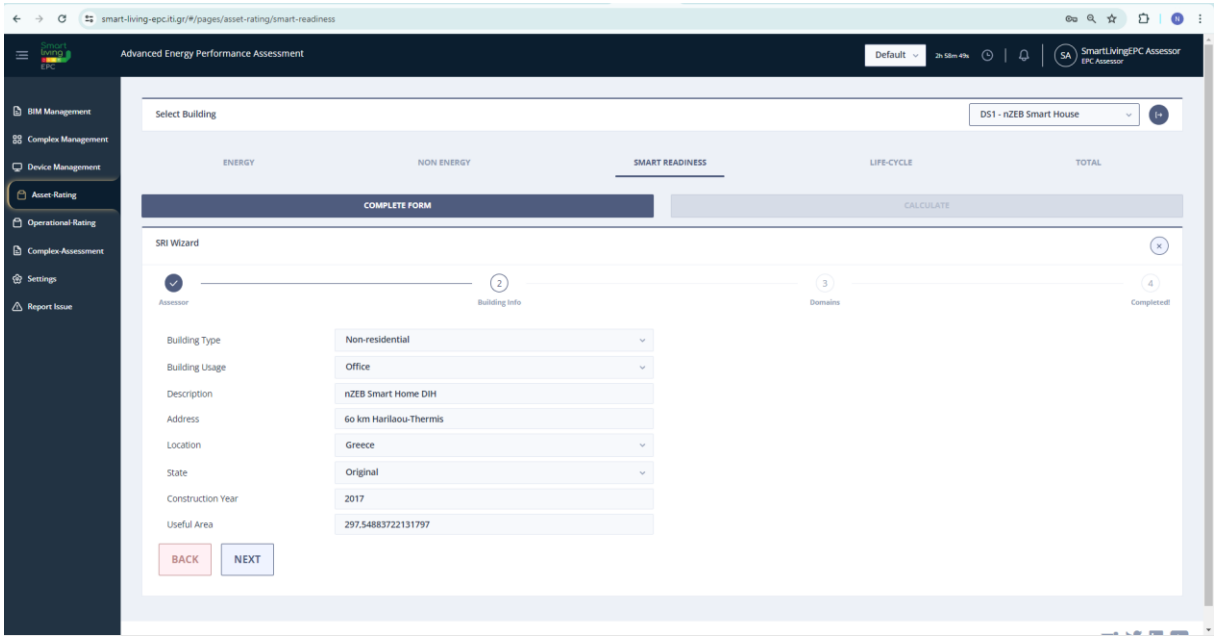


Figure 55: Smart Readiness tab - building characteristics input

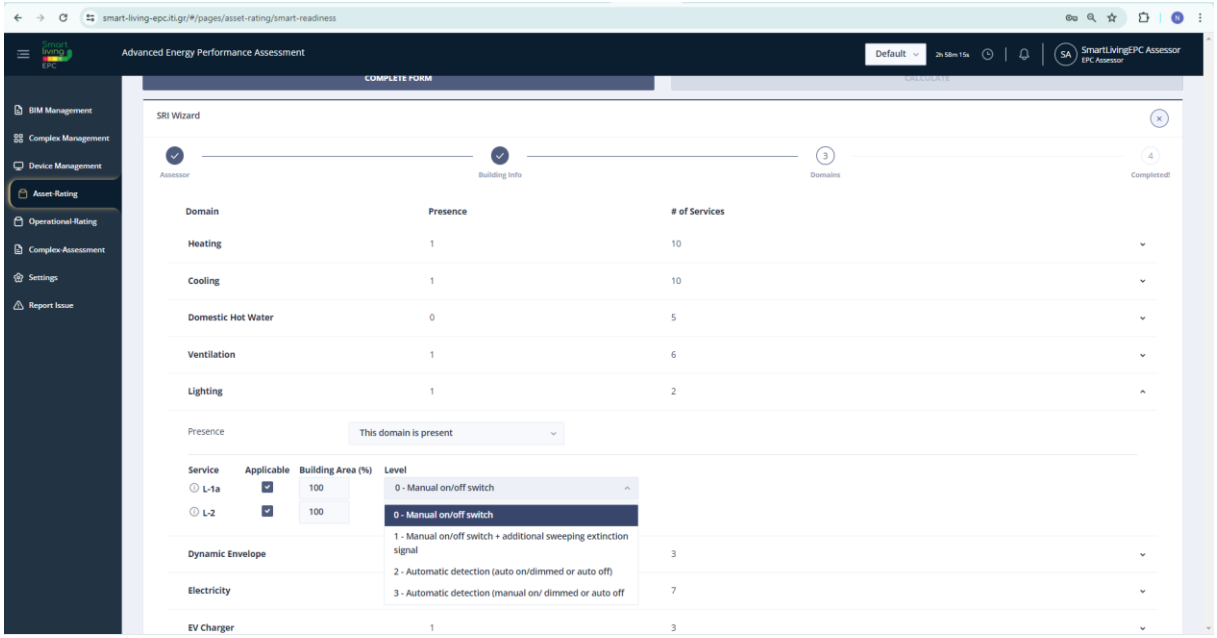


Figure 56: Smart Readiness tab - building domains and services input

The successful submission of the SRI assessment input information yields the results, as shown in Figure 57 and Figure 58, which are structured according to the *SRI Assessment package*[10] calculation sheet.

[10] https://ec.europa.eu/eusurvey/runner/SRI-assessment-package

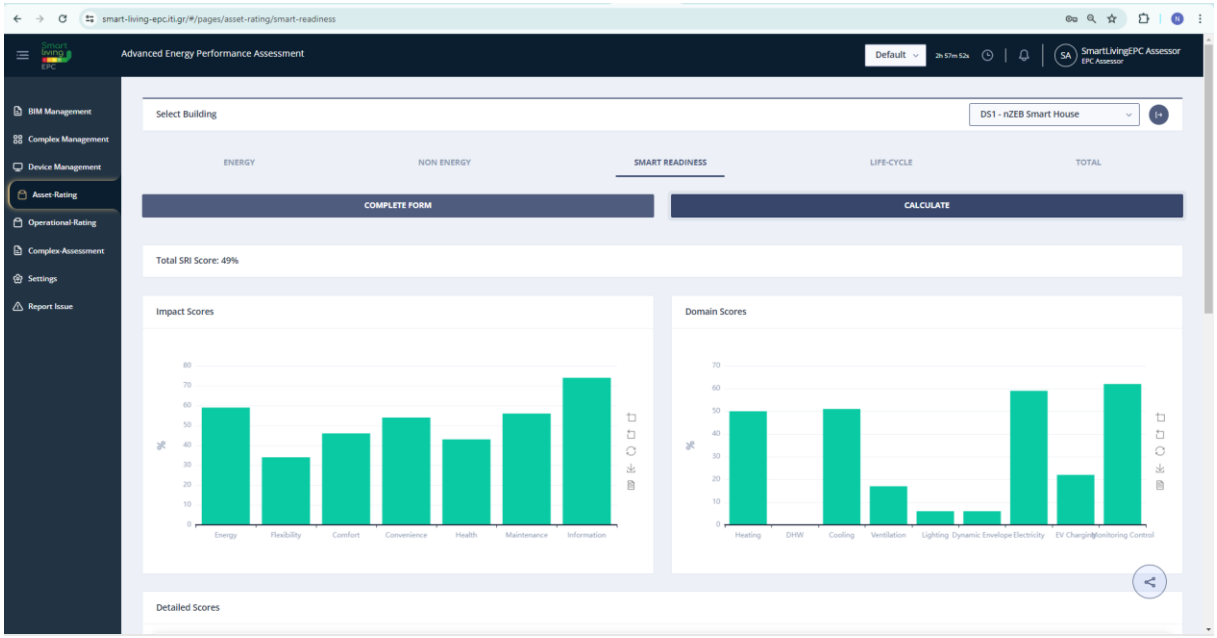


Figure 57: Smart Readiness tab - assessment results (1)

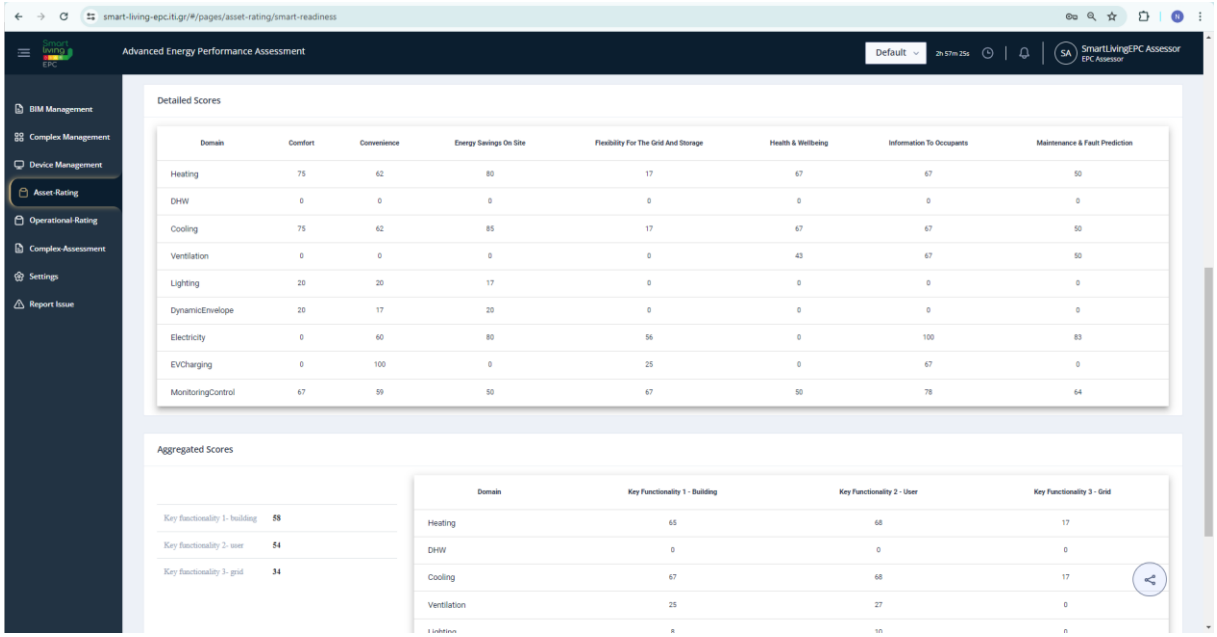


Figure 58: Smart Readiness tab - assessment results (2)

5.3.6.4 Total Asset Rating tab

The total asset rating classification for the building under study is calculated within this page (Figure 59). The results from each individual asset-based assessment (Energy, non-energy, life-cycle analysis, SRI) are utilized in order to determine the total asset rating score and corresponding class.

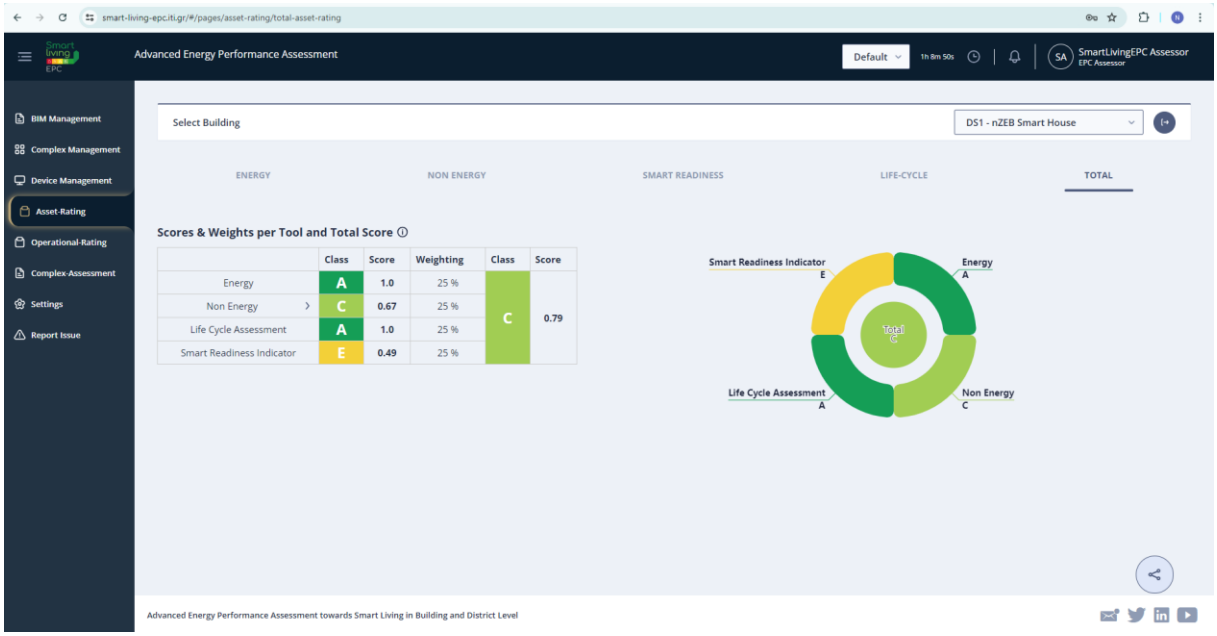


Figure 59: Total Asset Rating tab

5.3.7 Operational Rating page

5.3.7.1 Energy Indicators tab

The energy indicators (Figure 60), which are calculated based on actual measurements that are collected from the building onsite meters, are displayed in this page. The user is able to select the calculation scope (total, per area, per volume etc.) from a dropdown menu and view the corresponding indicator values in a dedicated bar graph. Additional informative metrics are also provided i.e. the allocation of the annual total building energy demand per energy carrier and energy use and the daily energy demand variation heat map for one year.

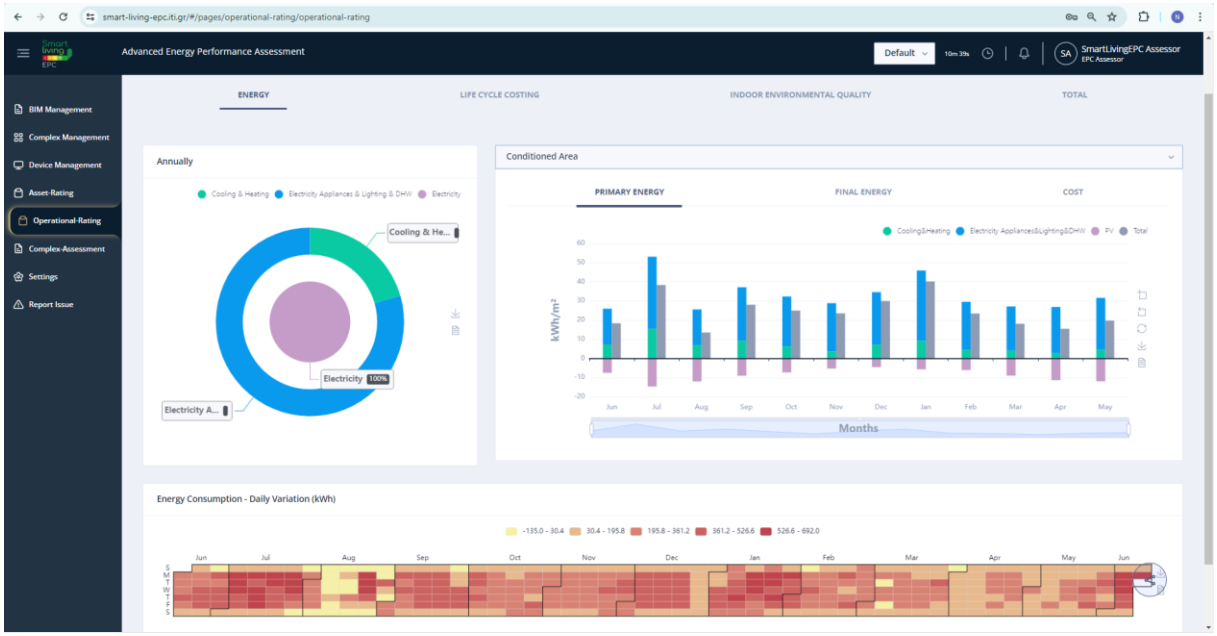


Figure 60: Operation-based energy indicators tab

5.3.7.2 Cost & Economic Indicators tab

This page hosts the life-cycle costing indicators. Prior to executing the calculation for the first time, the user should assign a monthly pricing scheme for each energy carrier that is relevant to the building under study, as shown in Figure 61. Consecutively, the as-designed and as-operated building costs are determined, using the provided energy prices and the asset-based and operation based indicators (as in sections 5.3.6.1 and 5.3.7.1), respectively. The results are displayed in Figure 62. Additionally, the as-predicted energy costs i.e. the nominal cost and the net present value (total, per energy carrier, per energy service) are calculated for the next ten years (Figure 63).

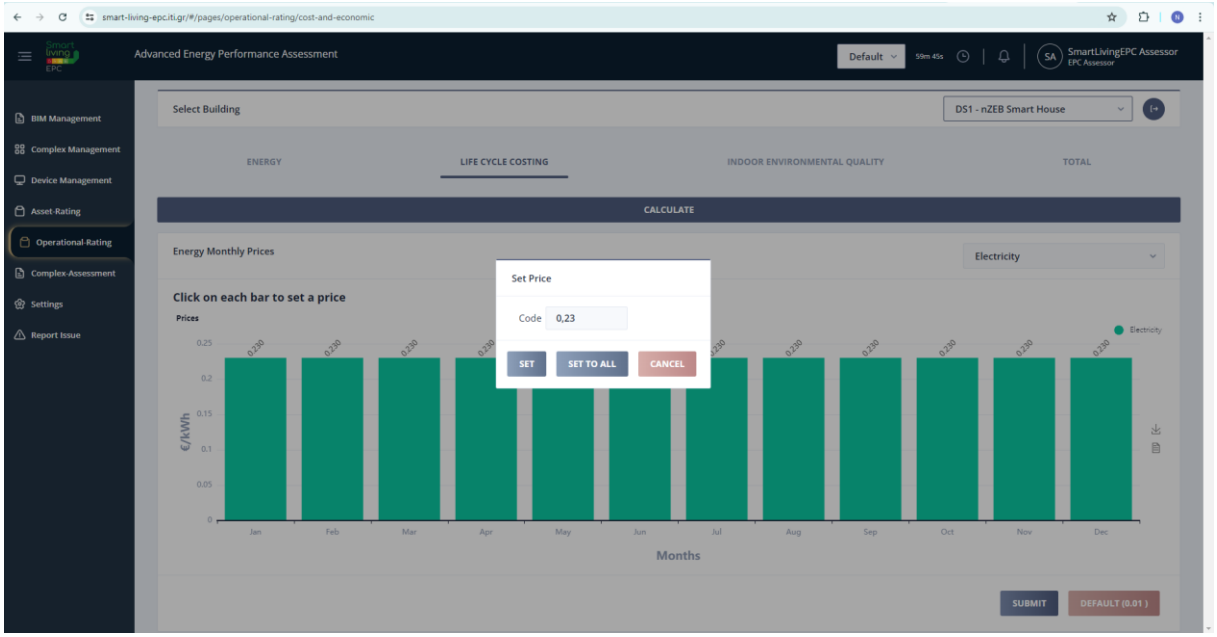


Figure 61: Cost & Economic Indicators tab - energy carrier monthly pricing setup

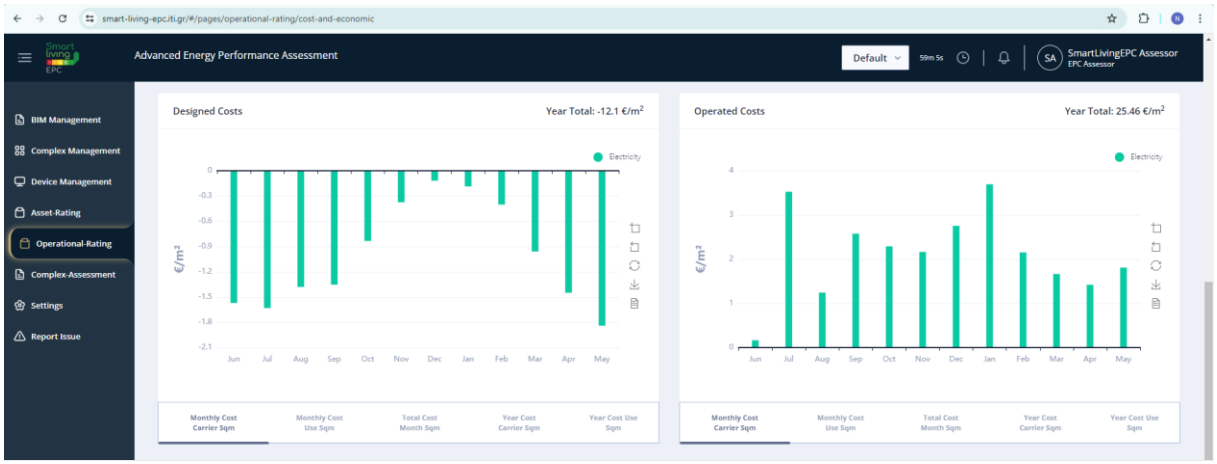


Figure 62: Cost & Economic Indicators tab - as-designed and as-operated costs

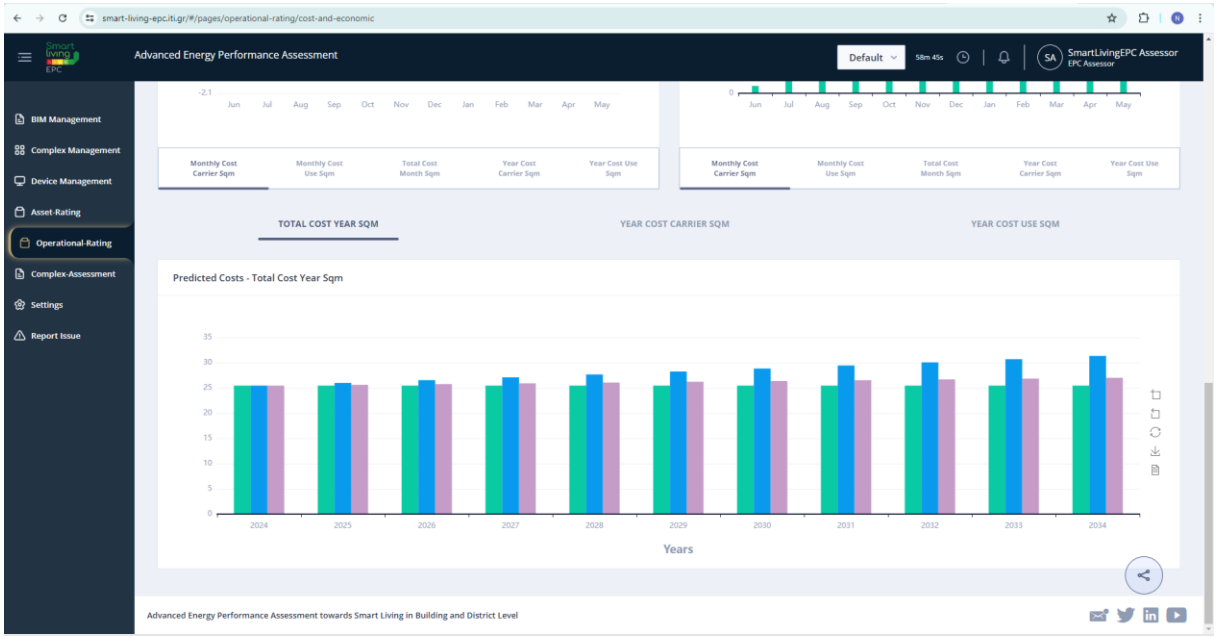


Figure 63: Cost & Economic Indicators tab - as predicted costs

5.3.7.3 Total Operational Rating tab

The total operational rating classification for the building under study is calculated within this page (Figure 64). The results from each individual operation-based assessment (Energy, life-cycle costing, indoor environmental quality) are utilized in order to determine the total operational rating score and corresponding class.

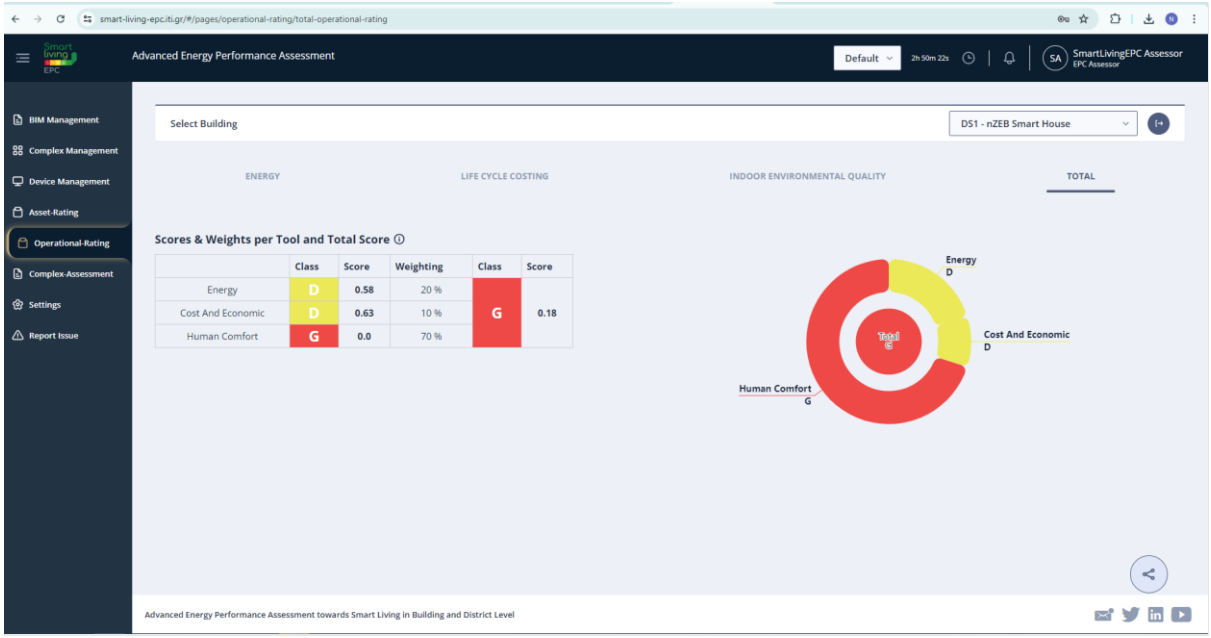


Figure 64: Total Operational Rating tab

5.3.8 Report issue page

This page (Figure 65) provides users with the ability to submit issue reports to the Web Platform management team. The following information should be inserted through the displayed input forms:

- A title for the issue to be reported
- An issue category (either software “bug” or desired feature that is considered useful to be implemented in a following release)
- A thorough description of the issue, formatted according to the user’s preferences
- An issue label, corresponding to the referred Web Platform functionality.

This process will create a dedicated issue in the Gitlab version control system that hosts the Web Platform software stack, in order to be addressed by the person responsible.

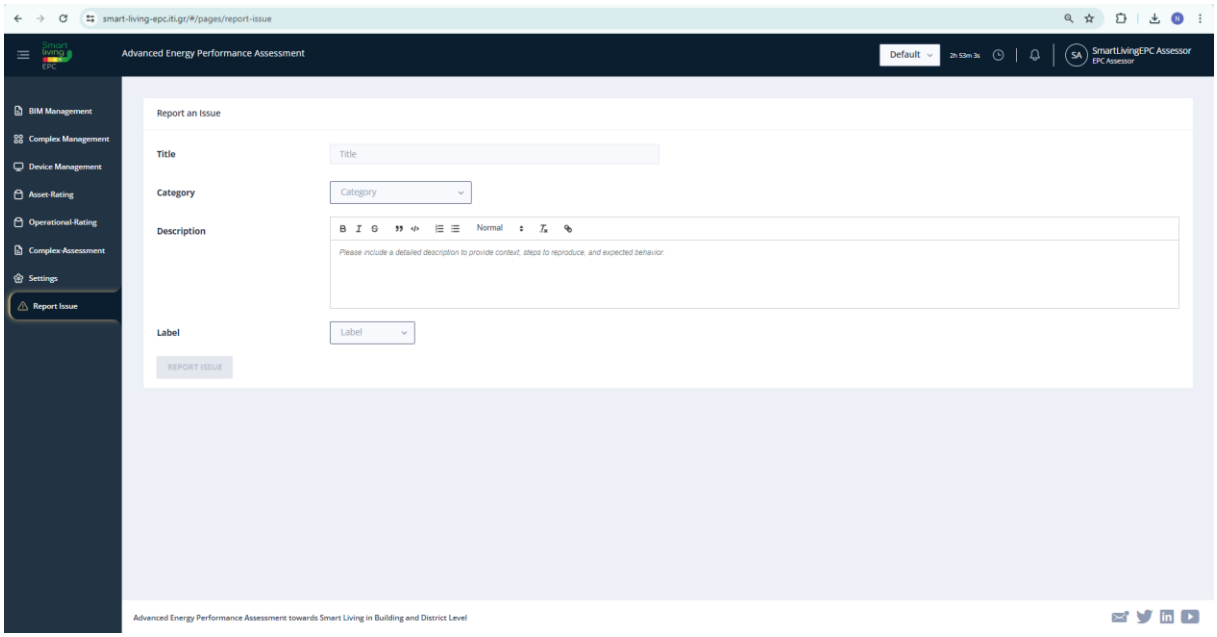


Figure 65: Report Issue page

6 Framework integration and acceptance testing

6.1 Integration plan

The Smart Living EPC software framework includes various components, which are grouped, deployed in different environments and managed by each responsible project partner. Figure 45 displays the architecture deployment view, as documented in D1.3 *SLEPC pilot analysis, Use case Scenarios and Framework Architecture v2*. It also highlights the main integration points that need to be implemented, in order to support all defined functionalities. The following sections describe each point, present its current integration status and lay out the expected integration timeline.

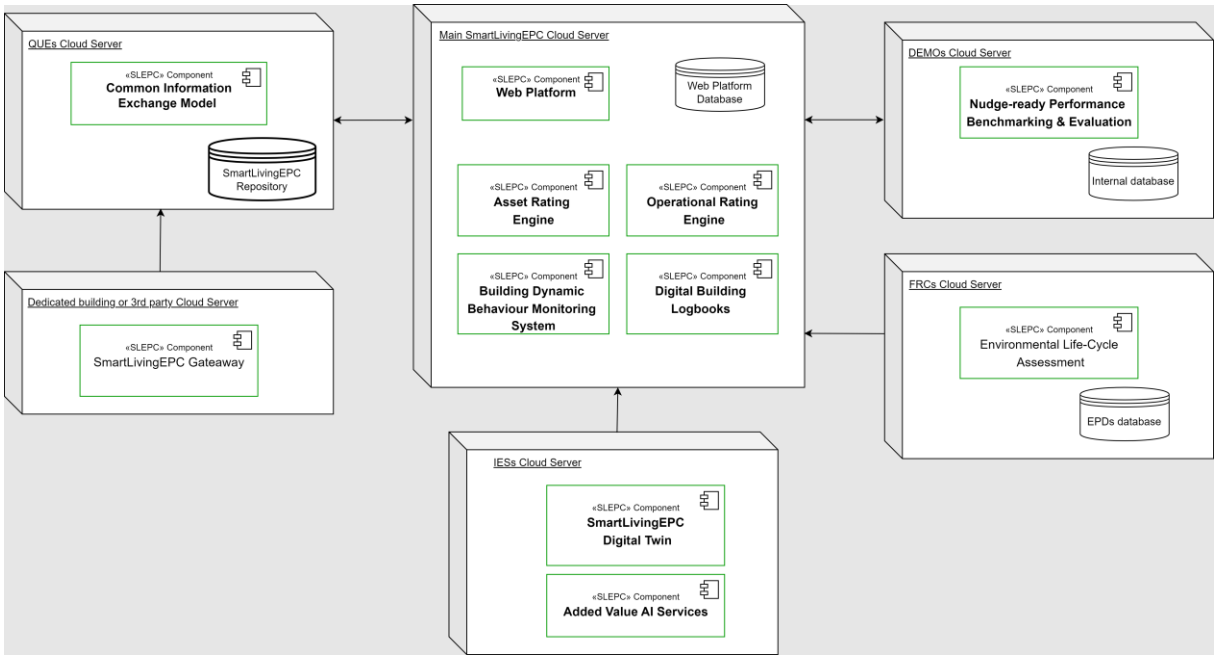


Figure 66: Smart Living EPC architecture deployment view

6.1.1 CIEM

The main integration with CIEM regards operations related to BIM files and building telemetry data from the onsite metering infrastructure. Additionally, it includes the connection to the Web Platform of a dedicated web interface for static and dynamic data visualization and monitoring.

Scope	Functionality	Integration	Status
BIM	Upload	Web Platform	Integration works planned to be initiated on M25 (Components for IFC serialization, deserialization, data extraction and CIEM's BIM related data model population have already
	Download	Web Platform	
	Update	Web Platform	
	Delete	Web Platform	

			been integrated within CIEM)
IoT data	Get measurements	Web Platform, Added Value AI tools	Integration works planned to be initiated on M25
	Collect data	Onsite monitoring infrastructure (sensors, meters, building management systems etc.)	Completed for demo site DS1; currently ongoing for other demo sites
Web interface redirection	Redirect to CIEM interface	Web Platform	Integration works planned to be initiated on M25

6.1.2 Building Digital Twin and Added Value AI tools

Scope	Functionality	Integration	Status
Digital Twin Visualization	Visualize building/complex level digital twin	Web Platform	Integration works planned to be initiated on M27
Added value AI tools results	Retrieve results	Web Platform	Integration works planned to be initiated on M27

6.1.3 LCA Analysis

Scope	Functionality	Integration	Status
LCA analysis results	Upload BIM file and retrieve results	Web Platform	Integration works planned to be initiated on M25

6.1.4 Performance Benchmarking and Evaluation

Scope	Functionality	Integration	Status
Tool setup	Send benchmarking data	Web Platform	Integration works planned to be initiated on M27
Tool results	Retrieve results	Web Platform	Integration works planned to be initiated on M27

6.2 Acceptance tests

As described in section 5.3.8, the ability to report software issues or propose new features has been integrated into the Smart Living EPC Web Platform, as the user feedback is considered valuable and can identify several areas of improvement. However, in order to deliver a fully functional and robust software prototype, specific testing procedures are required.

User acceptance tests (UATs) for the Web Platform aim to simulate real-world use and ensure that the platform meets user expectations. To this end, a UAT template has been drafted within the activities of T5.4 and is provided below.

TC-X-XX-XX	
Test title	*A short text indicating the test purpose*
Assignee	*The person/organization responsible for conducting the test*
Test date	*The date of the test*
Test priority	*The test priority (either HIGH, MEDIUM or LOW)*
Related use case(s)	*The use case(s) linked to the test, if applicable*
Preconditions	*Any actions/events that must have been taken place before performing the test*
Test steps	*A detailed description of the testing process, documented in discrete steps, e.g:* *1. step 1 description* *2. step 2 description* *etc.*
Expected result	*The expected test result, including any visual output, if applicable*
Actual result	*The actual test result, including any visual output, if applicable*
Pass/fail	*The test pass/fail result (either PASS/FAIL)*
Comments	*Any additional comments by the test assignee*

The following sections document the UATs that have been defined up to M24, focusing on three main key areas: *Functionality*, *Usability* and *Compatibility*. A device with active internet connection is required in order to perform each one of the defined tests.

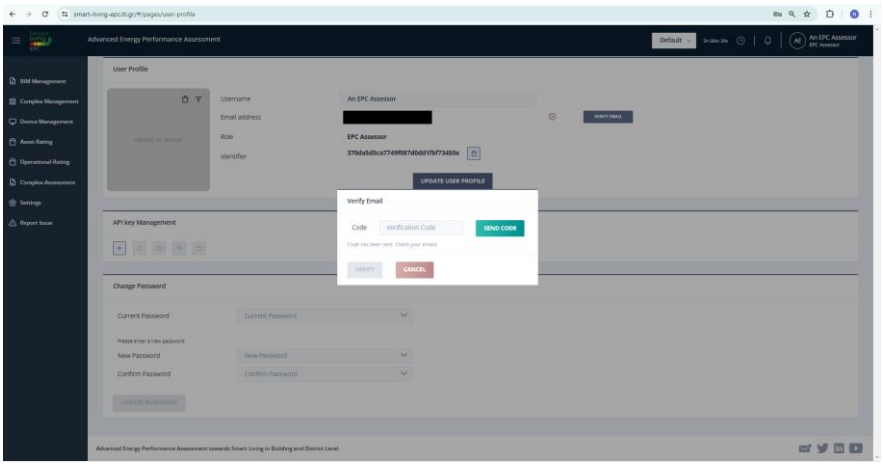
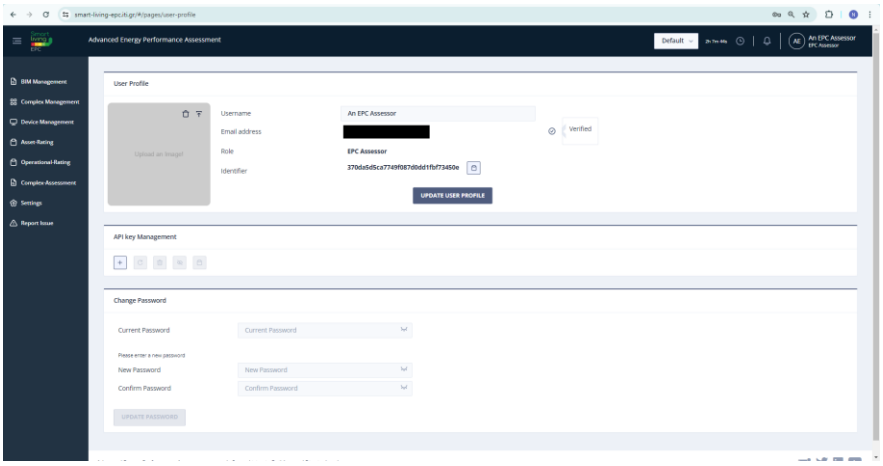
The next version of this deliverable will include the complete set of tests performed by members of the consortium, in alignment with the finalization of the Web Platform development and along with their actual results.

6.2.1 Functionality

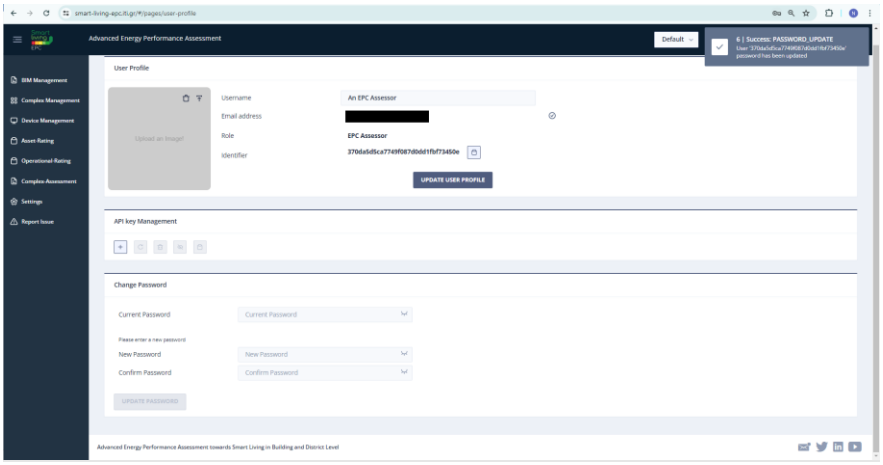
6.2.1.1 User account administration

TC-F-UA-01	
Test title	User registration
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	N/A
Preconditions	-
Test steps	1. Navigate to https://smart-living-epc.iti.gr/#/auth/register 2. Fill in the required information 3. Acknowledge the receipt of an admin approval email and log into the platform
Expected result	Admin approval email should be received within a working day and access to the platform, using the user's credentials, should be possible 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-UA-02	
Test title	User email verification
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	N/A
Preconditions	• The user must be logged into the platform

Test steps	1. Navigate to the user profile page. 2. Click on the “Verify email” button. 3. In the pop-up menu, click the “Send Code” button. 3. Log into your email account, open the received email and copy the provided verification code. 4. Paste the verification code in the corresponding input field and click OK.
Expected result	The user account status must be switched to “Verified”.  
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-UA-03	
Test title	User password reset

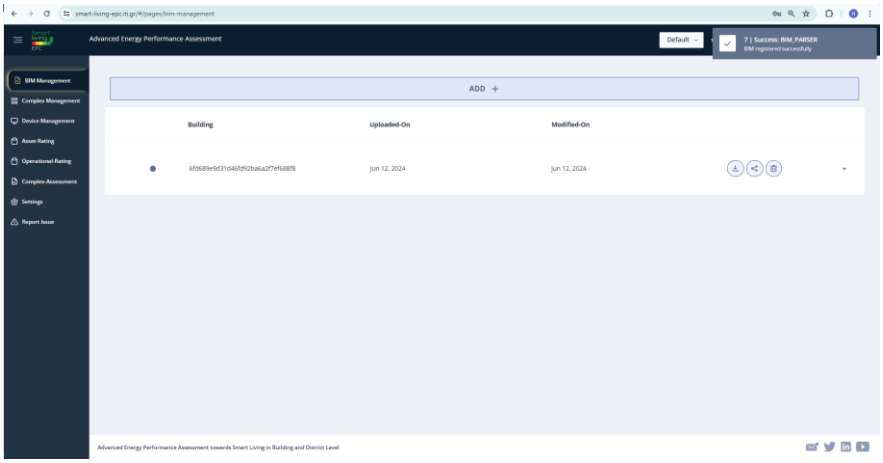
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	N/A
Preconditions	• The user must be logged into the platform
Test steps	1. Navigate to the user profile page and scroll down to the “Change Password” section. 2. Fill in the current password and the new password and click the “Update Password” button. 3. Log out of the Web Platform and log in again with the new password.
Expected result	The user must be able to log into the Web Platform with the new set password and an informative email regarding this action must be received. 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-UA-04	
Test title	User account modification (name, API key)
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	N/A
Preconditions	• The user must be logged into the platform
Test steps	1. Navigate to the user profile page. 2. Change the current user name and click on the “Update Profile” button.

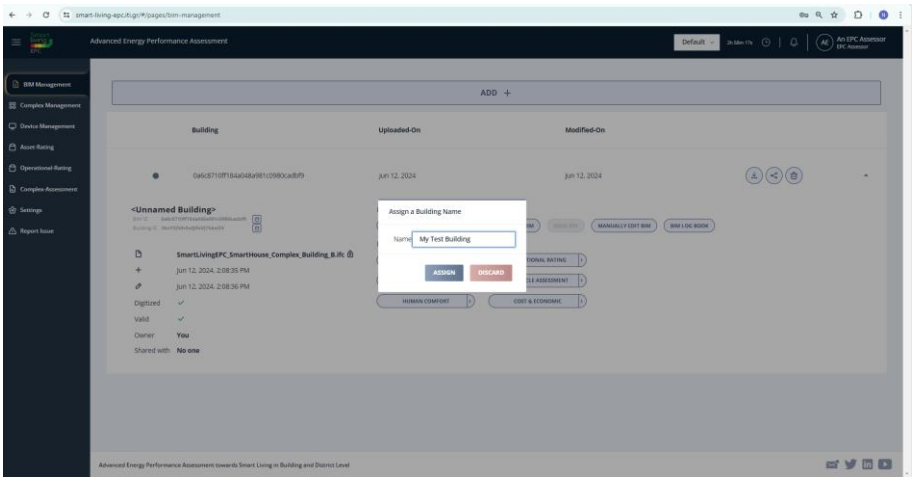
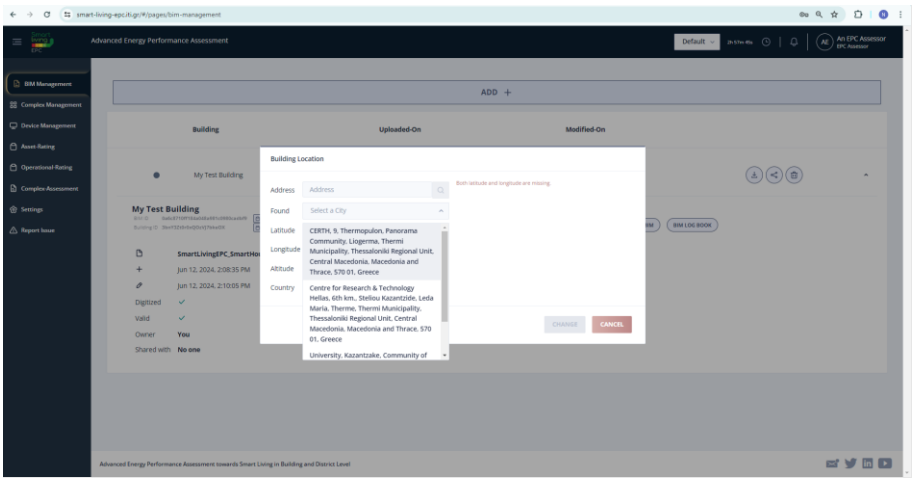
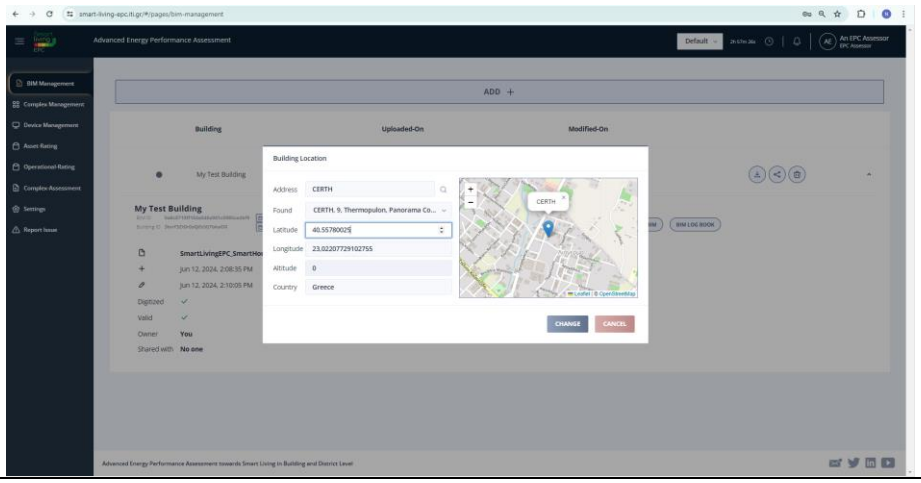
	3. Refresh the page and acknowledge the profile name modification. 3. Generate a new API key by clicking on the "+" button in the API Key Management section. 4. Regenerate, delete, view/hide and copy the API key using the corresponding buttons.
Expected result	The user name should be modified according to the user preference. The API key management functions must work as intended.
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

6.2.1.2 Setup and configuration

TC-F-SC-01	
Test title	Upload a BIM file
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	UC1.1
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Navigate to the BIM Management page 2. Select the "Add" button and then "Browse for file". 3. Select the BIM file from your local file system, await the file be loaded and then click the "Upload" button.
Expected result	The BIM file is uploaded successfully and appears as an entry in the same page.

	
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-SC-02	
Test title	Assign/change BIM file name and coordinates
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	UC1.1
Preconditions	• The user must be logged into the platform • The BIM file must be uploaded to the Web Platform.
Test steps	1. Navigate to the BIM Management page 2. Select a BIM file. 3. Click on the “Assign name” or “Change name” button and type in the new name. 4. Click on the “Assign” or “Change” button to apply the changes. 4. Click on the “BIM coordinates” button. 5. Either type in an address identifier and select one of the appearing options or type in the building’s latitude/longitude directly in the corresponding input fields. 6. Click on the “Change” button to apply the changes.
Expected result	The name and building coordinates are updated.

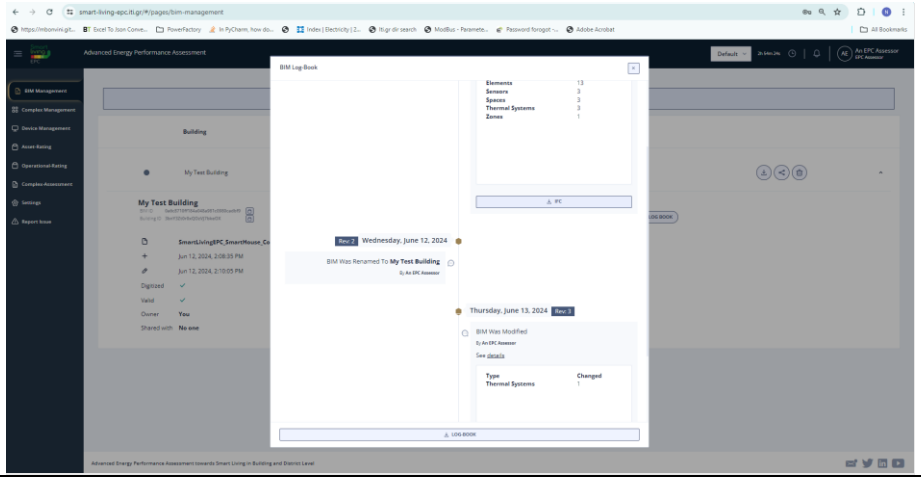
	  
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*

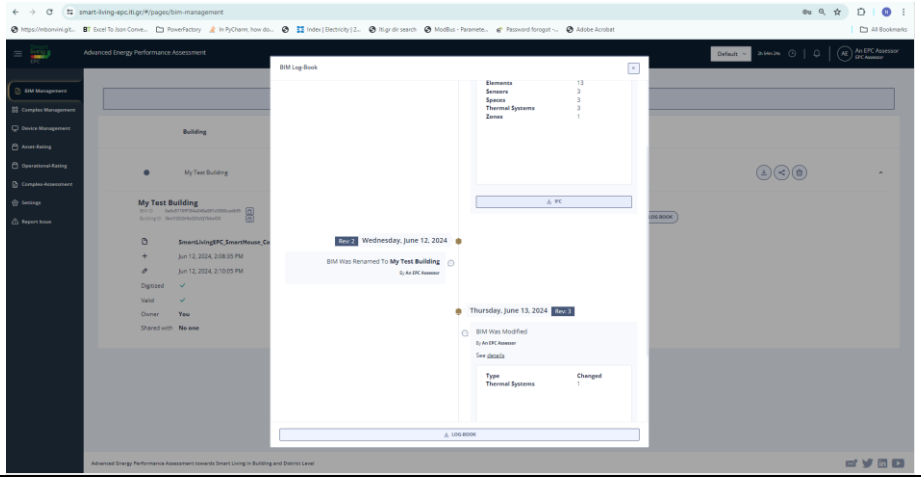
Comments	Since the building address identifier relies on an external service, results might not be obtainable for every building. In such a case, the building coordinates should be provided explicitly.

TC-F-SC-03	
Test title	Share BIM file
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	MEDIUM
Related use case(s)	-
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform • The ID of the user that needs access to the BIM file should be available
Test steps	1. Navigate to the BIM Management page 2. Select a BIM file. 3. Select the “Share BIM” button and enter the provided user ID in the input field
Expected result	Access to the BIM file is granted for another platform user.
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	The successful BIM file access provision is also depicted in the Building Logbook (see TC-F-SC-05)

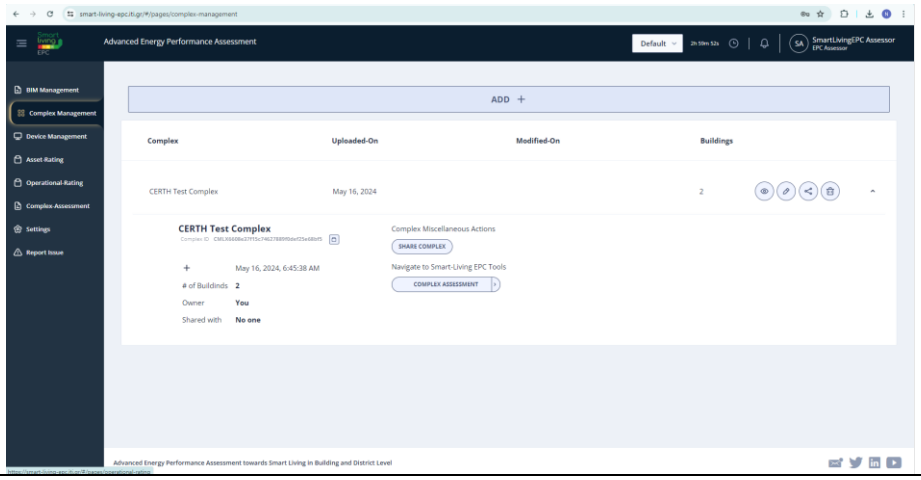
TC-F-SC-04	
Test title	Edit BIM file
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	MEDIUM
Related use case(s)	UC1.1, UC1.2
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Navigate to the BIM Management page 2. Select a BIM file. 3. Select the “Edit BIM” button.

	4. Expand one of the building level groups and select an item to be edited. 5. Add or modify an item parameter in the input form.
Expected result	BIM file parameters are edited successfully.
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	The successful BIM file modification is also depicted in the Building Logbook (see TC-F-SC-05)

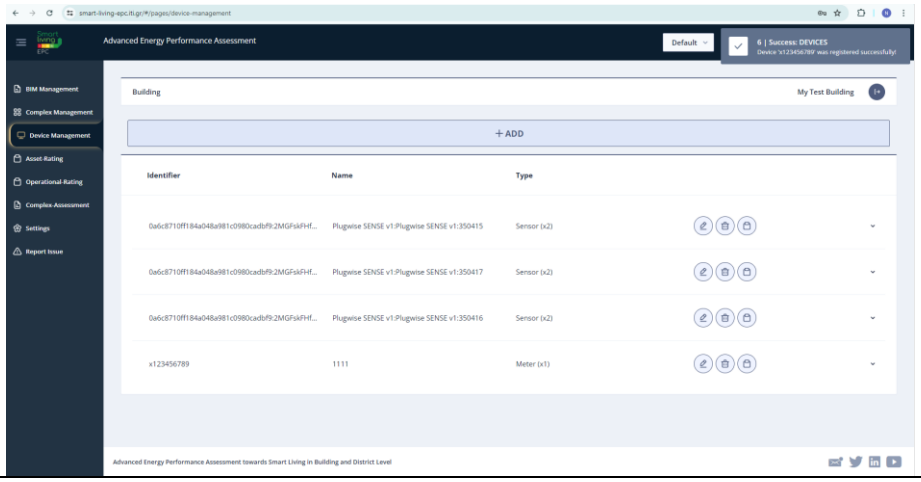
TC-F-SC-05	
Test title	Display building logbook
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	UC7.1
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Navigate to the BIM Management page 2. Select a BIM file. 3. Select the “Building Logbook” button. 4. Ensure any changes applied to the building entity have been documented in the appearing graph.
Expected result	The Building Logbook is loader correctly and all changes are documented. 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-SC-05	
Test title	Display building logbook
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	UC7.1
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Navigate to the BIM Management page 2. Select a BIM file. 3. Select the “Building Logbook” button. 4. Ensure any changes applied to the building entity have been documented in the appearing graph.
Expected result	The Building Logbook is loader correctly and all changes are documented. 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-SC-06	
Test title	Setup and share a building complex
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH

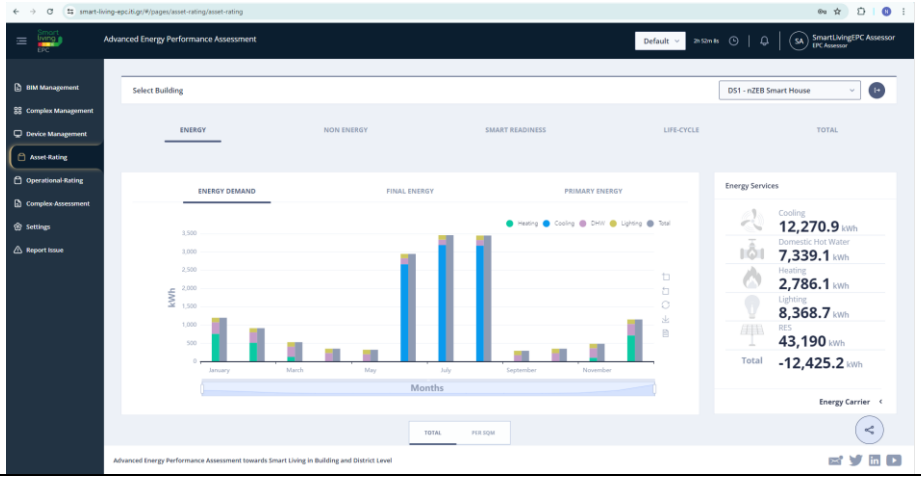
Related use case(s)	UC3.5, UC4.5,
Preconditions	• The user must be logged into the platform • At least two BIM files must be available to the user (either uploaded or shared by other users) • The locations of the buildings must be assigned (as in TC-F-SC-02) and both be within 1 km radial area. • The ID of the user that needs access to the building complex should be available
Test steps	1. Navigate to the Complex Management page 2. Select the “Add” button and then select the building that acts as a basis for the complex creation. 3. Select one or more nearby buildings, as shown in the list and in the map, indicating the search area. 4. Select the “Create” button in order to finalize the building complex setup. 5. Select the “Share Complex” button and enter the provided user ID in the input field.
Expected result	The building complex is created, is accessible through the same page and can be shared with other users. 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-SC-07	
Test title	Setup building monitoring devices
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH

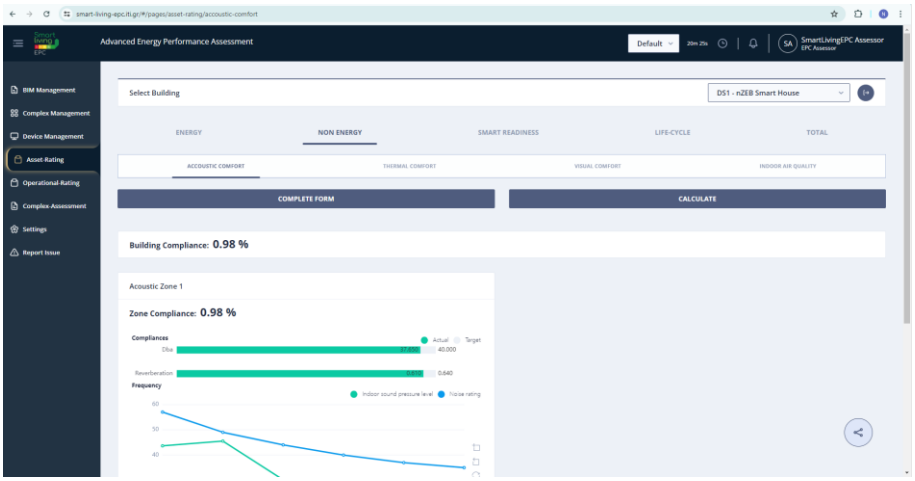
Related use case(s)	UC2.2, UC2.3
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Navigate to the Device Management page 2. Select the "Add" button and then select the type of the device (sensor/meter) that corresponds to the actual device. For meters, also select the energy carrier and energy service. Click next. 3. Select the thermal zone and space where the device is located. For meters (if applicable), also select the spaces and the systems to which the device's measurements refer. Click next 4. Add a name and a public ID for the device. Click next and complete the setup
Expected result	The new device is registered and added to the list of this page. 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

6.2.1.3 Core functionalities

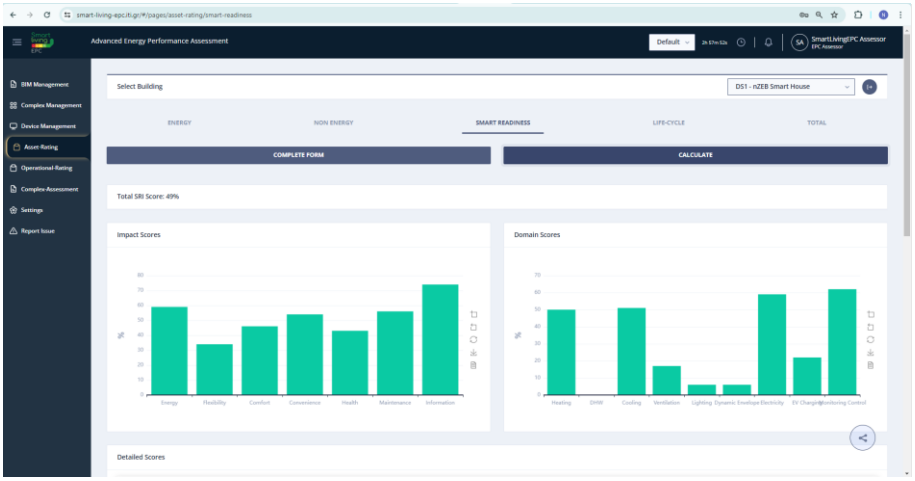
TC-F-CF-01	
Test title	Calculate the building energy indicators (asset-based)
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	UC3.1

Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Navigate to the Asset Rating page/Energy tab. 2. (Optional) in case a validation form appears and is required to be filled, insert the required input parameters. 3. View the asset-based energy indicators
Expected result	The asset-based energy indicators are displayed within this page. 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

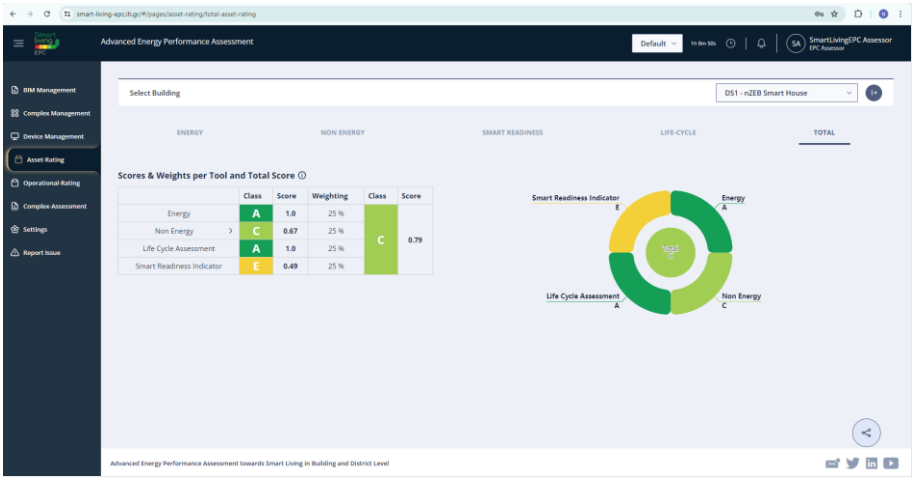
TC-F-CF-02	
Test title	Calculate the building non-energy indicators
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	UC3.1
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Navigate to the Asset Rating page/Non-energy tab. 2. Fill in the required information in each step of the setup process. 3. Select the “Calculate” button and view the results.

Expected result	The non-energy indicators results are displayed within each tab (e.g. acoustic comfort indicators, as shown below). 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

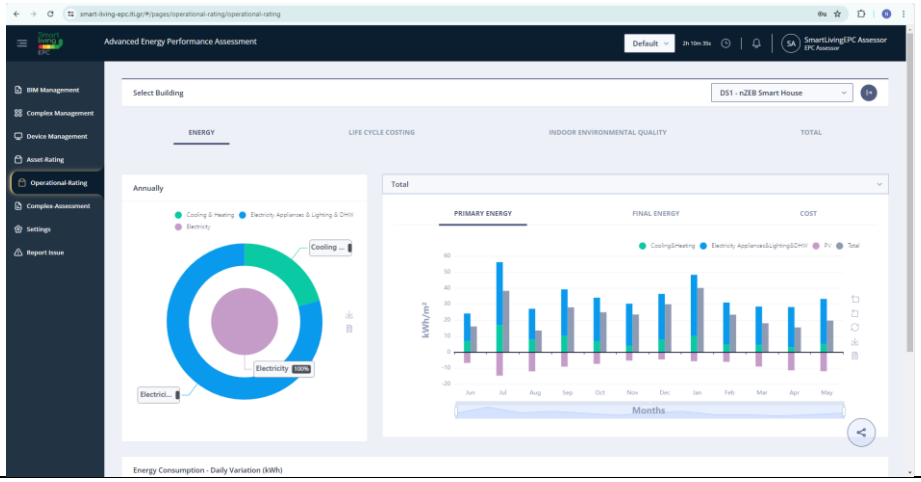
TC-F-CF-03	
Test title	Calculate the building smart readiness
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	UC3.2
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Navigate to the Asset Rating page/Smart Readiness tab. 2. Fill in the required information in each step of the setup process. 3. Select the “Calculate” button and view the results.

Expected result	The SRI results are displayed within this page. 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

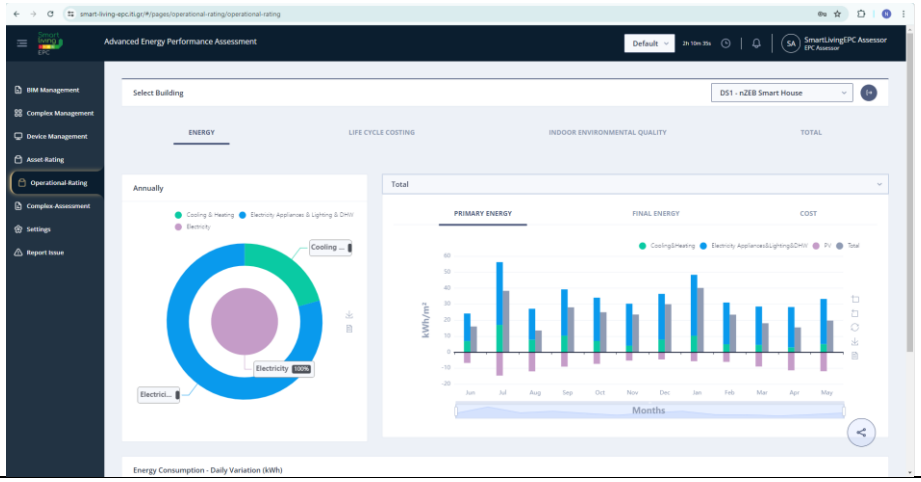
TC-F-CF-04	
Test title	Calculate the total asset rating
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	UC3.4
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Perform tests TC-F-CF-01, TC-F-CF-02 and TC-F-CF-03. 2. Navigate to the Asset Rating page/Total tab. 2. View the results.

Expected result	The total asset rating results are displayed within this page. 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

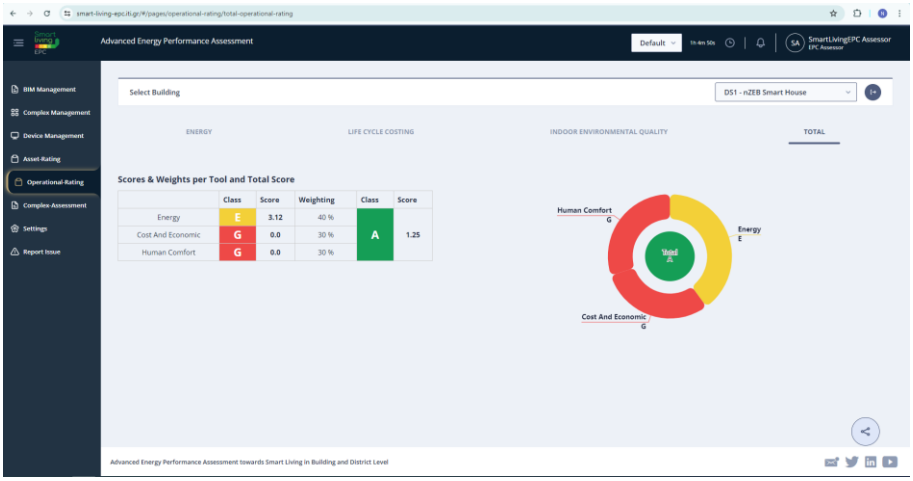
TC-F-CF-05	
Test title	Calculate the building energy indicators (operation-based)
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	UC4.1
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Navigate to the Operational Rating page/Energy tab. 2. (Optional) in case a validation form appears and is required to be filled, insert the required input parameters. 3. View the operation-based energy indicators

Expected result	The operation-based energy indicators are displayed within this page. 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-CF-06	
Test title	Calculate the building LCC indicators
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	UC4.3
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Navigate to the Operational Rating page/Cost & Economic tab. 2. Fill-in the energy pricing data required for the calculation and click on the “Calculate” button. 3. View the LCC indicators

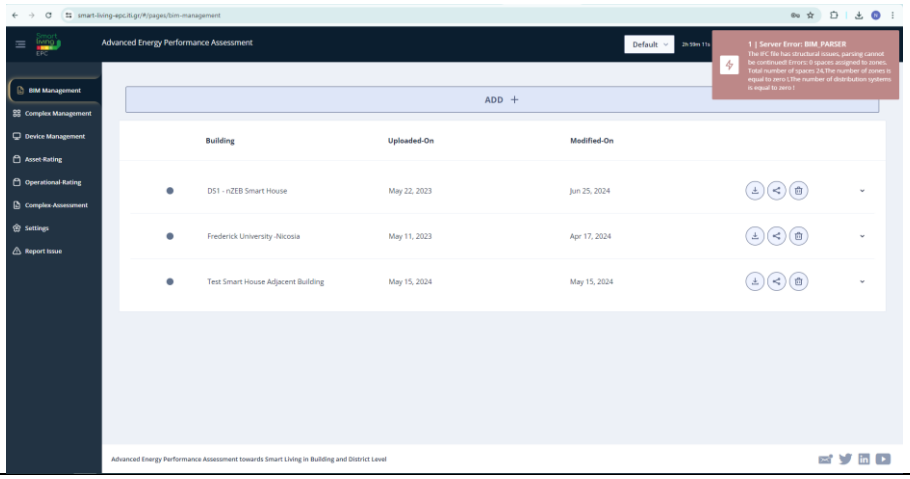
Expected result	The LCC indicators are displayed within this page. 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	Since the calculation of the LCC indicators utilizes the energy indicators results (both asset-based and operation-based), tests TC-F-CF-01 and TC-F-CF-03 should be executed successfully prior to executing this test.

TC-F-CF-07	
Test title	Calculate the total operational rating
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Related use case(s)	UC4.4
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Perform tests TC-F-CF-05 and TC-F-CF-06. 2. Navigate to the Operational Rating page/Total tab. 3. View the results.

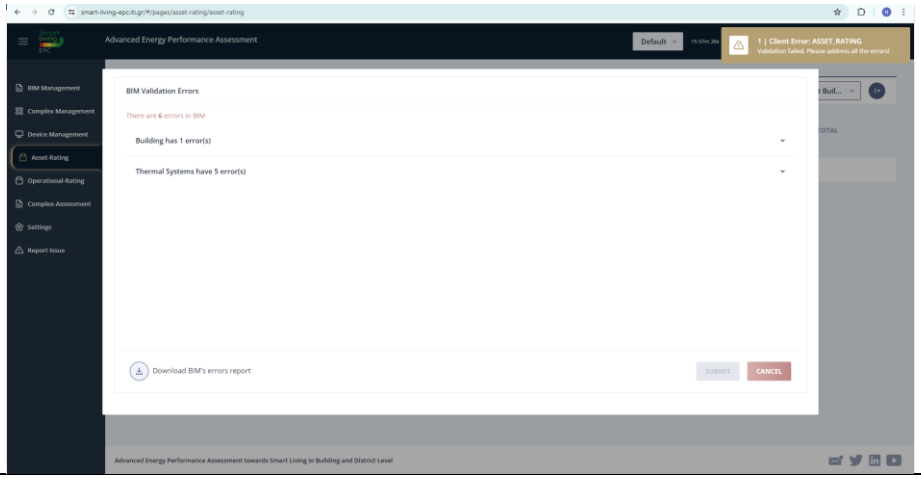
Expected result	The total operational rating results are displayed within this page. 
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

6.2.1.4 Error handling

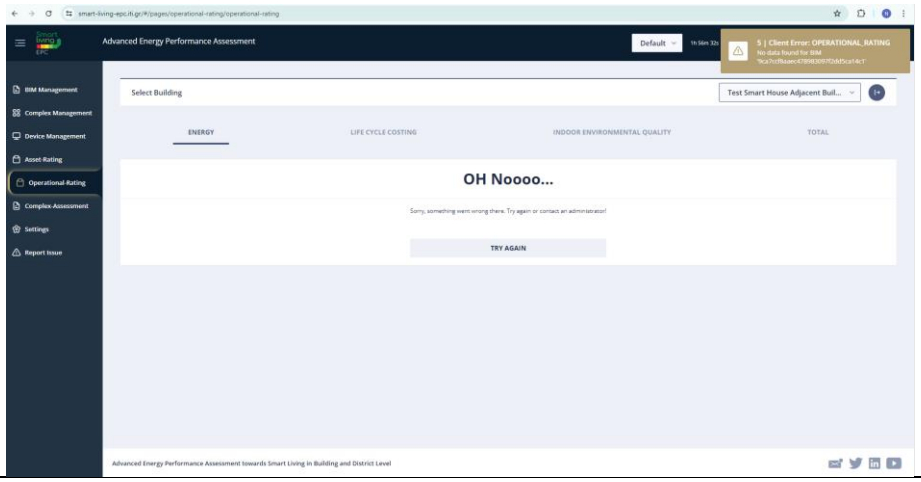
TC-F-EH-01	
Test title	BIM file upload error
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Relate use case(s)	-
Preconditions	• The user must be logged into the platform • A BIM file that has not been already validated (e.g. uploaded for the first time) must be available
Test steps	1. Navigate to the Asset Rating page/Energy tab 2. Acknowledge the appearing error indicating the minimum design requirement violation that needs to addressed
Expected result	An appropriate error is raised informing about the requirement that is not met in the uploaded BIM file (e.g. missing zones, as below)

	
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

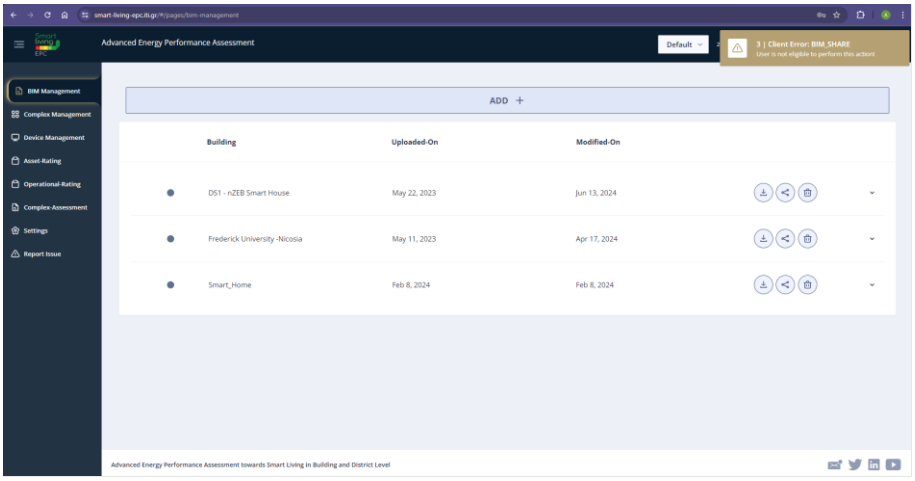
TC-F-EH-02	
Test title	Validation error
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Relate use case(s)	-
Preconditions	• The user must be logged into the platform • A BIM file that has not been already validated (e.g. uploaded for the first time) must be available and follow a few design requirements in order to be processable by the Web Platform
Test steps	1. Navigate to the Asset Rating page/Energy tab 2. Acknowledge the raising of a validation error and the provision of a corresponding validation input form
Expected result	An appropriate validation error is raised in combination with a validation input form in order to fill-in missing required parameters.

	
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-EH-03	
Test title	Calculation execution error (missing historical building IoT data)
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Relate use case(s)	-
Preconditions	• The user must be logged into the platform • A BIM file must be available and follow a few design requirements in order to be processable by the Web Platform • No devices should be registered for the specific building in order to simulate data unavailability
Test steps	1. Navigate to the Operational Rating page/Energy tab. 2. Acknowledge the raising of an execution error (missing data)
Expected result	An appropriate execution error (missing input measurements) is provided.

	
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-EH-04	
Test title	User eligibility error (BIM file sharing)
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Relate use case(s)	-
Preconditions	• The user must be logged into the platform • A BIM file must be available, which follows a few design requirements in order to be processable by the Web Platform and has been shared to other users. • The ID of a user that has access to the BIM file is available.
Test steps	1. Navigate to the BIM Management page and select a shared BIM file. 2. Select the “Share BIM” button, insert the other user’s ID and select the “Revoke” button. 3. Acknowledge the user eligibility error that is raised.
Expected result	A user eligibility error is raised, regarding the BIM file sharing revoke action.

	
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

6.2.2 Usability

TC-F-U-01	
Test title	Interactive graphs
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	LOW
Relate use case(s)	-
Preconditions	• The user must be registered in the Web Platform
Test steps	1. Connect to the Web Platform 2. Navigate to interfaces that embed interactive graphs (e.g. Asset Rating page/Operational Rating page) 3. Use the different graph functionalities (e.g. zooming/downloading as image/viewing data)
Expected result	The use of the platform's interactive graphs should be intuitive.
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-U-02	
Test title	Actions/calculations execution speed

Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	MEDIUM
Relate use case(s)	-
Preconditions	• The user must be registered in the Web Platform
Test steps	1. Connect to the Web Platform 2. Perform all the tests under sections 6.2.1.1-6.2.1.3 3. Assess the execution speed of actions/calculations in each case
Expected result	The user should not experience lags or extended waiting times in all cases.
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	Although hard to quantify, since the execution speed in each case depends on the amount of data provided/requested and the complexity of each operation, the following thresholds should be respected: • Calculations: under 10 seconds • Data upload: under 5 seconds • Data download: under 10 seconds

TC-F-U-03	
Test title	Graphics
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	MEDIUM
Relate use case(s)	-
Preconditions	• The user must be registered in the Web Platform
Test steps	1. Connect to the Web Platform 2. Perform all the tests under sections 6.2.1.1-6.2.1.3 3. Assess the visual appeal of the produced results
Expected result	The overall look and feel of the Web Platform must be visually appealing and consistent, resulting into easy comprehension.
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-U-04	
Test title	Interpretation of results

Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	HIGH
Relate use case(s)	-
Preconditions	• The user must be registered in the Web Platform
Test steps	1. Connect to the Web Platform 2. Perform all the tests under sections 6.2.1.1-6.2.1.3 3. Assess the clarity of results in each test case.
Expected result	The user should interpret all provided results easily.
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

6.2.3 Compatibility

TC-F-C-01	
Test title	Web Platform access from various browsers
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	LOW
Relate use case(s)	-
Preconditions	• The user must be registered in the Web Platform
Test steps	1. Connect to the Web Platform from different available web browsers 2. Perform the tests under 6.2.1
Expected result	The tests carried out should produce the same visual result in all web browsers.
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

TC-F-C-02	
Test title	Web Platform access from various devices
Assignee	*To be filled by the tester*
Test date	*To be filled by the tester*
Test priority	LOW
Relate use case(s)	-

Preconditions	• The user must be registered in the Web Platform
Test steps	1. Connect to the Web Platform from different available devices (e.g. personal computer, laptop, tablet, smart phone etc.) 2. Perform the tests under 6.2.1
Expected result	The tests carried out should produce the same visual result in all devices, without significantly deteriorating the user experience
Actual result	*To be filled by the tester*
Pass/fail	*To be filled by the tester*
Comments	*To be filled by the tester*

7 Conclusions

As regards the T5.1 AI Added Value Tools and specifically the thermal comfort engine, the comprehensive process of developing the machine learning (ML) model was detailed, including data preprocessing and the various steps involved. The training dataset, used in conjunction with the pilot dataset, enabled evaluation of the model's performance and potential. The results demonstrated promising outcomes; however, there remains significant room for improvement:

- The pilot dataset needs to incorporate user feedback. Currently, predictions are based solely on observed behavior, but it is crucial to validate these predictions with actual user input to enhance the model's reliability and relevance. This issue is not isolated to the pilot dataset; other pilot studies exhibit the same limitation. Incorporating feedback mechanisms across all pilot datasets will be essential for a holistic improvement in model accuracy and applicability.
- The ML model requires further tuning to achieve better accuracy. Fine-tuning the model parameters, exploring additional features, and employing advanced algorithms may contribute to improved performance.

While the initial results are encouraging, addressing these key areas will be vital for advancing the robustness and precision of the ML model. Future work should focus on integrating user feedback, standardizing feedback collection across all pilot datasets, and refining the model for optimal accuracy. These steps will ensure that predictive capabilities are both validated and enhanced, ultimately contributing to more reliable and effective ML applications.

Anomalies Detection Engine (T5.1) involves addressing several challenges and exploring future enhancements to maximize its capabilities and applicability. The key challenges encountered during system development as well as potential avenues for future work are:

- Handling Missing Data: Ensuring the engine can robustly handle missing or incomplete data is a significant challenge. This involves developing strategies for data imputation and handling gaps in time-series data, which can affect the accuracy of anomaly detection.
- Rule Complexity: Managing complex rules and their interactions is another challenge. As users define more complex rules, the system needs to ensure that all rules are applied correctly and that interactions between rules do not produce false positives or negatives.
- Scalability: Ensuring the engine can efficiently process large datasets in a timely manner is crucial for real-world applications. Scalability is essential to handle the substantial data volumes generated by building sensors and systems, ensuring timely detection and response to anomalies.

Future work for the anomaly detection system involves several key enhancements. Integrating machine learning models will significantly improve the system's capability to detect anomalies by identifying complex patterns and relationships in the data, thereby enhancing accuracy and robustness. Extending the engine to handle real-time data streams is another crucial step, enabling immediate detection and response to anomalies. This real-time processing will help prevent issues and maintain optimal building operations by providing timely alerts and insights. Additionally, enhancing the reporting features by incorporating more detailed analytics and visualizations will offer deeper insights into the detected anomalies, helping users understand their root causes and develop more effective response strategies. Finally, improving the user interface to make it more user-friendly for defining rules and viewing reports will increase the system's accessibility and usability, encouraging broader adoption and more effective utilization of the anomaly detection engine.

The updated version of the aforementioned components, along with the functional description and development information of the remaining AI services, will be included in the second version of the same deliverable.

Additionally, this deliverable provides a comprehensive overview of the Nudge-ready Performance Benchmarking and Evaluation Tool developed as part of T5.2. The tool assesses building performance by collecting and analyzing design and as-operated data, offering evaluations, benchmarks, and recommendations to improve building efficiency. The methodology and functionalities of its three subcomponents—Evaluation, Benchmarking, and Recommendation—was defined. Implementation specifics for each subcomponent was outlined, followed by a description of the testing process. The feasibility study on AI techniques and their potential applications, discussed in Section 4.4, demonstrates the integration of advanced AI methodologies to enhance the tool's effectiveness. . Future works include integration of the tool within the web platform, testing and evaluation of the component, and modification.

The final results of T5.2 and detailed analytics will be presented in D5.2, set for publication in M33 of the project, marking a significant milestone in the ongoing development and refinement of these advanced AI-driven tools.

This deliverable also provides a comprehensive overview of the SLEPC Visualization Platform (T5.3), outlined in Chapter 5, which details its requirements, platform architecture, and user interfaces. The platform encompasses various functionalities essential for managing building data and enhancing user interaction, including the Welcome page, Main dashboard, user profile pages, BIM Management page, Building Complex Management page, Device Management page, Asset Rating page, Operational Rating page, and Report issue page.

Chapter 6 delves into the framework integration and acceptance testing (T5.4), emphasizing the integration plan for critical components such as CIEM, Building Digital Twin, Added Value AI tools, LCA Analysis, and Performance Benchmarking and Evaluation tool. The acceptance tests evaluate the platform's functionality, usability, and compatibility, ensuring it meets the project's objectives and user requirements effectively.

Those sections demonstrate the project's progress in developing a robust and user-centric SLEPC Visualization Platform, integrating advanced technologies to support enhanced building management and performance evaluation.

The final version of the SLEPC Web Platform will be presented in the forthcoming deliverable, D5.2. This next iteration will incorporate further refinements and enhancements based on ongoing development and feedback.

8 References

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ANNEX A: SLEPC User Stories

EPC Assessor

Phase	Sub-phase	Epic	Story	Success Criterion
1.Account Creation / Management				
	1.1 Registration / First Login			
		1.1.1 User needs to register to the platform using an e-mail through a secure approach		
			1.1.1.1 User wants to insert e-mail and password to register	
				1.1.1.1.1 The user should easily understand the fields to insert e-mail and password and press register
				1.1.1.1.2 The user should not be allowed to continue if the fields are empty.
			1.1.1.2 User wants advanced security upon registration	
				1.1.1.2.1 The user should be informed if the e-mail is not correct and not allowed to continue.
				1.1.1.2.2 The user should be given a second field to verify the password. If the password is not the same with the above, the user should not be allowed to continue
				1.1.1.2.3 The user should check that he/she has read terms and conditions and agrees to them.
				1.1.1.2.4 The user should be informed after pressing register that the registration is successful and an activation link has been sent
				1.1.1.2.5 Software is designed within Security and Policy by Design principles and guides.

			The user should be able to read at any given time the Privacy Statement
	1.1.2 User needs to verify his/her e-mail		
		1.1.2.1 The user wants to receive an e-mail to verify his/her e-mail before gaining access to the platform	
			1.1.2.1.1 The user receives automatically an e-mail which includes a brief explanation and an activation link
			1.1.2.1.2 The user can click the link, open in a browser a SLEPC page and see a notification that his/her account is successfully activated
			1.1.2.1.3 The user should be notified that the activation link is temporary and needs to activate within a certain time after receiving the e-mail
			1.1.2.1.4 The user will be informed that the account is not activated and cannot login if he/she hasn't pressed their activation link sent to them
	1.1.3 User needs to first login and set profile		
		1.1.3.1 The user wants to login and set up a profile on first login including mandatory and optional fields	
			1.1.3.1.1 The user will be able to login right after activating the account
			1.1.3.1.2 The user will be guided to a page to set his/her profile
			1.1.3.1.3 The user should insert Name, Surname, Profession (drop down), type of user (drop down), and a

				few more mandatory fields. The user should not be able to proceed if the profile is not completed
			1.1.3.2 The user wants to do use SLEPC Account Management either from a PC or a mobile device	
				1.1.3.2.1 All pages should be responsive and functional either through PC or a mobile device
				1.1.3.2.2 All pages should be operational in all known browsers (Firefox, Chrome, Opera, Edge, Safari)
	1.2 Profile Management			
		1.2.1 Profile modification		
			1.2.1.1 The user wants at any given time to be able to change their profile	
				1.2.1.1.1 The user can click on their profile and change at once most of their information and click save/update
2.Application of the SLEPC				
	2.1 SLEPC Platform			
		2.1.1 Open the SLE Web Platform		
			2.1.1.1 The user would like to open the SLE Web Platform	
				2.1.1.1.1 The user is able to open SLE Web Platform through the SLEPC page.
				2.1.1.1.2 The user is able to directly access SLEPC through a url, only if already logged in.
				2.1.1.1.3 The platform should request the user to log in if not.
	2.2 Main page			

	2.2.1 Onboarding		
		2.2.1.1 As a user, the first time I open the Web Platform, I want to receive an introduction to how it works.	
			2.2.1.1.1 - An introduction to how the web application works is displayed the first time the web application is launched.
			2.2.1.1.2 - The introduction to how the web application works is not displayed when the web application is launched subsequently.
			2.2.1.1.3 - The explanatory content is available to web application users in the respective functional areas.
		2.2.1.2 As a user, I want the app to be displayed in English, so that I can understand how to use the app.	
			2.2.1.2.1 The configured system language is set in English by default
	2.2.2 Information and Instructions for Using the App		
		2.2.2.1 As a user, I want to have access to a FAQ list, so that I can find answers to questions I might have about the app.	
			2.2.2.1.1 The web application will either contain a link to a web page with FAQs, which is displayed in a browser window, or the web page will be displayed within the app itself.
		2.2.2.2 As a user, I want to have access to instructions, so	

		that I can understand the app and its functions.	
			2.2.2.2.1 An explanation of the app's various functions will be provided.
2.3 Building Registration	2.3.1 Adding a building		
		2.3.1.1 The user would like to easily press a button and through a form add the building information	
			2.3.1.1.1 If it's the first building inserted the user will only see "Add building" in the home page 2.3.1.1.2 If it is not the first building the user will see in the home page of the web app a list of buildings with some information per building. There will be an extra button to "Add building"
		2.3.1.2 The user would like to add as many info as possible so that he/she can have a digital archive of the building in the Building's Profile Page	
			2.3.1.2.1 The user should be able to add General Info - Name of the building - Country - City -Altitude (Perhaps selecting from a map would allow parsing all three) - Tags - Comments 2.3.1.2.2 The user should be able to add BIM files and open the 3D model of the building through 3D BIM visualizer

			2.3.1.2.3 The user should be able to add other technical manuscripts 2.3.1.2.4 The user should be able to add additional info like bills 2.3.1.2.5 The user should be able to press a save button to store everything 2.3.1.2.6 The user should be able to import files from they are device. 2.3.1.2.7 The platform should be able to receive different types of file formats.
		2.3.1.3 The user would like to assign to a building owner the created building so that the user building owner could access the building	
			2.3.1.3.1 The user will be able to fill in the user id of a building owner in a dedicated form to assign this building to "building owner" 2.3.1.3.2 The user should be able to fill in an e-mail if a user id is not available so that the building owner could create an account.
	2.3.1 Building list management		
		2.3.1.1 As a user, I want to see all my buildings in a list with the most important information easily readable	
			2.3.1.1.1 The user should be able to see all the buildings in a table view 2.3.1.1.2 The user should be able to see basic info in the table such as - Name - Address - Owner - Type of building - Completed Certificates (EPC(A-D), SRI(%),etc.)

			- Last updated - buttons for view/ edit and delete
			2.3.1.1.3 To delete an entry the user should be asked twice
			2.3.1.1.4 The user should be able to see at a glance the number of buildings
		2.3.1.2 As a user, I want to sort the buildings as it suits me	
			4.1.3.2.1 The user should be able to sort the buildings by date, by name, by stage etc.
	2.3.2 Building Profile		
		2.3.2.1 As a user, I want to see all my certifications in the building profile	
			2.3.2.1.1 The user should see the status of each certification (if it has started and not completed)
			2.3.2.1.2 The user should see the final result of the certification(s) finalized (e.g. EPC - Class D, SRI - 45%, ...)
			2.3.2.1.3 The user should be able to press on the certificate and get the report
		2.3.2.2 As a user, I want to issue a new certificate for the selected building	
			2.3.2.2.1 The user should click a button for a new certificate
			2.3.2.2.2 The user should be able to select which one of the available certificates wants to issue (multiple choices)

			2.3.2.2.3 Upon selection the user should be guided to a new page
2.4 Dynamic			
	2.4.1 Equipment		
		2.4.1.1 As a user, I want to be able to assign new monitoring/sensoring equipment.	
			2.4.1.1.1 The user should be able to add new monitoring/sensoring equipment to the building.
			2.4.1.1.2 The platform should have step by step installation with instructions.
	2.4.2 Data Access		
		2.4.2.1 As a user, I want to be able to view my buildings measurements	
			2.4.2.1.1 The user should be able to view the measured values of the building depending on the sensor and measurement.
			2.4.2.1.2 The platform should provide the appropriate visualization of the data.
		2.4.2.2 As a user I want to view the measurements directly to my building.	
			2.4.2.2.1 The platform should provide a 3D visual representation of the user's building with different views of the measured data.
			2.4.2.2.2 The platform should check if there is an IFC model available.
			2.4.2.2.3 The user should have provided an IFC model.
2.5 Issue a certificate			
	2.5.1 Check the BIM content	2.5.1.1 As a user, I want the BIM file to	

		automatically be checked to see if it contains all the required values.	
			2.5.1.1.1 The system should recognize and indicate to the user the missing values
		2.5.1.2 As a user, I want the system to indicate possible incorrect entries	
			2.5.1.2.1 The system should recognize possible incorrect entries to the field and inform the user
			2.5.1.2.2 Certain entries should not be allowed (e.g. in a field that requires a number, it should not be possible to type a letter).
	2.5.2 Set the envelope		
		2.5.2.1 As a user I would like to fill the forms with all available information from the BIM file	2.5.2.1.1 All the available properties should be filled in automatically
			2.5.2.1.2 The user should easily define neighboring buildings with some easy parameters (distance from each wall and total height)
			2.5.2.1.3 The user should easily be able to change properties filled from BIM
			2.5.2.1.4 The user should receive a warning before changing properties filled from BIM
	2.5.3 Define the Systems		
		2.5.3.1 As a user I would like an easy way to introduce the building systems, both the general and per thermal zone	

			2.5.3.1.1 The user should have a different dedicated view for general systems and systems per zone
			2.5.3.1.2 The user should be able to introduce general assets like CHP, Wind Generations and PV generation through easy to fill fields
			2.5.3.1.3 The user should be able to introduce per thermal zone Heating, Cooling, Ventilation, Domestic Hot Water, Solar Heating Panels, and Humidification systems
			2.5.3.1.4 Depending the Certificate selected to be issued the content may change to also include information that is needed for SRI
			2.5.3.1.5 The user should receive a warning before changing the information from BIM.
		2.5.3.2 As a user I want the app to be able to perform calculations automatically	
			2.5.3.2.1 The application should contain toolboxes for the automatic calculations e.g. systems' efficiency, for each system
		2.5.3.3 As a user, I want the system to indicate possible incorrect entries	
			2.5.3.3.1 The system should recognize possible incorrect entries
	2.5.4 Overview and Calculations		
		2.5.4.1 As a user, I want to see an overview of all the information provided in the envelope and systems in an easy to	

		understand way, in order to check one last time if everything is correct	
			2.5.4.1.1 In a single page the user should be able to see all the information in an easy to navigate way
			2.5.4.1.2 The user should be able to edit the fields / values
			2.5.4.1.3 The user should be able to sort the categories of the values to change their order
		2.5.4.2 As a user, I want to have a calculation button to execute the calculation process either per certificate or for all certificates originally selected	
			2.5.4.2.1 The user should have in an easy to find spot a calculation button.
			2.5.4.2.2 The calculation button should be enabled only if all fields are complete
			2.5.4.2.3 In case of multiple certificates, the user should be able to select which one to calculate (one, multiple, all...)
			2.5.4.2.4 If there is an error in the calculation and results cannot be produced, the user should be informed through a notification what went wrong.
		2.5.4.3 As a user, I want to have buttons for running the auxiliary services provided by SLE Framework	
			2.5.4.3.1 The user should have in an easy to find the running button for each service.
			2.5.4.3.2 If there is an error in the service and results cannot be produced, the user should be informed through a notification what went wrong.
	2.5.5 Indicators		

		2.5.5.1 As a user, I want to evaluate my building separately for each indicator. (Asset, LCC, IEQ etc.)	
			2.5.5.1.1 The platform should be able to perform assessment for each indicator separately.
	2.5.6 Results		
		2.5.6.1 As a User, I want some graphs that visualize the results of certificates or auxiliary services	
			2.5.6.1.1 A variety of graphs and visual analytics should be presented for each certificate or service
			2.5.6.1.2 Clear and easy to understand information should be available
		2.5.6.2 As a User, I want to export and download the report and additional info where available	
			2.5.6.2.1 For some of the certificates it should be possible to download a report
			2.5.6.2.2 For some of the auxiliary services it should be possible to download a report
2.6 Statistics			
	2.6.1 Check My Certificates per building (DBL)		
		2.6.1.1 As a User, I want to be able to see previous Certificates	
			2.6.1.1.1 The user should be able to select to see certificates issued on a previous time
			2.6.1.1.2 The user should be able to see not only the results but also the parameters for the historical Certificate

		2.6.2 Check my overall statistics (DBL)		
			2.6.2.1 As a user, I want to be able to see statistics per certificate for all my buildings	
				2.6.2.1.1 The user should be able to see how many certificates, when in time, and other statistics for each type of certificate
				2.6.2.1.2 The user should be able to export a statistics report
	2.7 Digital Building Logbook			
		2.6.3 Digital Building Logbook functionality		
			2.6.3.1 As a user, I want to view my Building Unit's Record.	
				2.6.3.1.1 The platform should keep a record of the changes made in the building. (DBL)
				2.6.3.1.2 The record should be in different view orders (chronological, type, etc.).
3. Public Database				
	3.1 Neighborhood Level			
		3.1.1 Neighborhood assessment		
			3.1.1.1 As a user, I want to assign my building to a neighborhood.	
				3.1.1.1.1 The platform should assign a neighborhood id to each neighborhood.
				3.1.1.1.2 The user should be able to assign the building to a neighborhood using the buildings address or id.

				3.1.1.1.3 The platform should associate the building address to the correct neighborhood.
		3.1.2 User's Buildings		
			3.1.2.1 As a user, I want to be able to search my building in the neighborhood.	
				3.1.2.1.1 The user should be able to search their building using a building id or address
				3.1.2.1.2 The platform should have a separate page for the public available building data.
				3.1.2.1.3 The platform should have a search function.
	3.2 Benchmarking			
		3.2.1 Compare Buildings with other buildings from the neighborhood		
			3.2.1.1 As a user, I want to view other building's Performance and compare them to mine.	
				3.2.1.2 The user should be able to select and view neighborhood buildings.
				3.2.1.3 The platform should allow only the public available buildings/building data to be viewed.
4. Account Deletion				
	4.1 Delete Account and Unsubscribe			
		4.1.1 Delete Account and Unsubscribe		
			4.1.1.1 As a User I want to be able to delete my SLEPC account and remove my data	

				4.1.1.1.1 An option for deleting an account should be provided to User 4.1.1.1.2 A link for confirming the deleting should be created
			4.1.1.2 As a User I want to unsubscribe from the email list	
				4.1.1.2.1 If the User wants to delete his/her account a page should be popped up for unsubscribing from emails lists

Building Complex Assessor

Phase	Sub-phase	Epic	Story	Success Criterion
1.Account Creation / Management				
	1.1 Registration / First Login			
		1.1.1 User needs to register to the platform using an e-mail through a secure approach		
			1.1.1.1 User wants to insert e-mail and password to register	
				1.1.1.1.1 The user should easily understand the fields to insert e-mail and password and press register 1.1.1.1.2 The user should not be allowed to continue if the fields are empty.
			1.1.1.2 User wants advanced security upon registration	
				1.1.1.2.1 The user should be informed if the e-mail is not correct and not allowed to continue. 1.1.1.2.2 The user should be given a second field to verify the password. If the password is not the same with the

			above, the user should not be allowed to continue 1.1.1.2.3 The user should check that he/she has read terms and conditions and agrees to them. 1.1.1.2.4 The user should be informed after pressing register that the registration is successful and an activation link has been sent 1.1.1.2.5 Software is designed within Security and Policy by Design principles and guides. The user should be able to read at any given time the Privacy Statement
	1.1.2 User needs to verify his/her e-mail		
		1.1.2.1 The user wants to receive an e-mail to verify his/her e-mail before gaining access to the platform	
			1.1.2.1.1 The user receives automatically an e-mail which includes a brief explanation and an activation link 1.1.2.1.2 The user can click the link, open in a browser a SLEPC page and see a notification that his/her account is successfully activated 1.1.2.1.3 The user should be notified that the activation link is temporary and needs to activate within a certain time after receiving the e-mail 1.1.2.1.4 The user will be informed that the account is not activated and cannot login if he/she hasn't pressed their activation link sent to them
	1.1.3 User needs to first login and set profile		

			1.1.3.1 The user wants to login and set up a profile on first login including mandatory and optional fields	
				1.1.3.1.1 The user will be able to login right after activating the account
				1.1.3.1.2 The user will be guided to a page to set his/her profile
				1.1.3.1.3 The user should insert Name, Surname, Profession (drop down), type of user (drop down), and a few more mandatory fields. The user should not be able to proceed if the profile is not completed
			1.1.3.2 The user wants to do use SLEPC Account Management either from a PC or a mobile device	
				1.1.3.2.1 All pages should be responsive and functional either through PC or a mobile device
				1.1.3.2.2 All pages should be operational in all known browsers (Firefox, Chrome, Opera, Edge, Safari)
	1.2 Profile Management			
		1.2.1 Profile modification		
			1.2.1.1 The user wants at any given time to be able to change their profile	
				1.2.1.1.1 The user can click on their profile and change at once most of their information and click save/update
2.Application				
	2.1 SLEPC Plartform			

	2.1.1 Open the SLE Web Platform		
		2.1.1.1 The user would like to open the SLE Web Platform	
			2.1.1.1.1 The user is able to open SLE Web Platform throught the SLEPC page. 2.1.1.1.2 The user is able to directly access SLEPC through a url, only if already logged in. 2.1.1.1.3 The platform should request the user to log in if not.
2.2 Main page			
	2.2.1 Onboarding		
		2.2.1.1 As a user, the first time I open the Web Platform, I want to receive an introduction to how it works.	
			2.2.1.1.1 - An introduction to how the web application works is displayed the first time the web application is launched. 2.2.1.1.2 - The introduction to how the web application works is not displayed when the web application is launched subsequently. 2.2.1.1.3 - The explanatory content is available to web application users in the respective functional areas.
		2.2.1.2 As a user, I want the app to be displayed in English, so that I can understand how to use the app.	
			2.2.1.2.1 The configured system language is set in English by default

		2.2.2 Information and Instructions for Using the App		
			2.2.2.1 As a user, I want to have access to a FAQ list, so that I can find answers to questions I might have about the app.	
				2.2.2.1.1 The web application will either contain a link to a web page with FAQs, which is displayed in a browser window, or the web page will be displayed within the app itself.
			2.2.2.2 As a user, I want to have access to instructions, so that I can understand the app and its functions.	
				2.2.2.2.1 An explanation of the app's various functions will be provided.
	2.3 Neighborhood Registration			
		2.3.1 Adding a Neighborhood		
			2.3.1.1 The user would like to easily press a button and through a form add the building complex/neighborhood information.	
				2.3.1.1.1 If it's the first building complex inserted the user will only see "Add building complex" in the home page
				2.3.1.1.2 If it is not the first building complex the user will see in the home page, a list of building complexes with some information per building. There will be an extra button to "Add building complex"

		2.3.1.2 The user would like to add as many info as possible so that he/she can have a digital archive of the building complex in the Building complex Profile Page	
			2.3.1.2.1 The user should be able to add General Info for the building complex 2.3.1.2.2 The user should be able to add other technical manuscripts 2.3.1.2.3 The user should be able to add additional info like bills 2.3.1.2.4 The user should be able to press a save button to store everything
	2.3.2 Management		
		2.3.2.1 As a user, I want to see all my building complexes in a list with the most important information easily readable	
			2.3.2.1.1 The user should be able to see all the building complexes/neighborhoods in a table view 2.3.2.1.2 To delete an entry the user should be asked twice 2.3.2.1.3 The user should be able to see at a glance the number of building complexes/neighborhoods
		2.3.2.2 As a user, I want to sort the building complexes as it suits me	
			2.3.2.2.1 The user should be able to sort the buildings by date, by name, by stage etc.
	2.3.3 Building complex Profile		

		2.3.3.1 As a user, I want to complete all the required information in order to calculate KPIs related with the assessed building complex	
			2.3.3.1.1 The user should be able to extract data from the online databases regarding the building units that are part of the building complex in order to use them for KPIs calculations
			2.3.3.1.2 The user should retrieve the required information for the building complex from the database
			2.3.3.1.3 The user should be able to add manually the rest of the required information for the building complexes
2.4 KPIs calculation and results			
	2.4.1 KPIs calculation		
		2.4.1.1 As a user, I want to calculate KPIs related with the assessed building complex	2.4.1.1.1 The user should see the status of each KPI (if it has started and not completed)
			The user should be able to press a button in order to calculate each KPI
			2.4.1.1.2 The user should see the calculated KPIs
			2.4.1.1.3 The user should be able to press a button and get a corresponding report
	2.4.2 Results		
		2.4.2.1 As a user, I want to publish the final building complex assessment to other users.	
			2.4.2.1.1 The user should be able to easily publish the assessment.

				2.4.2.1.2 The platform should have a page with the public available data. 2.4.2.1.3 The user cannot publish personal information.
3. Account Deletion				
	3.1 Delete Account and Unsubscribe			
		3.1.1 Delete Account and Unsubscribe		
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Buildng Owner

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		1.2.1 Profile modification		
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				1.2.1.1.1 The user can click on their profile and change at once most of their information and click save/update
2.Application				
	<u>2.1 SLEPC Plartform</u>			
		2.1.1 Open the SLE Web Platform		
			2.1.1.1 The user would like to open the SLE Web Platform	
				2.1.1.1.1 The user is able to open SLE Web Platform through the SLEPC page. 2.1.1.1.2 The user is able to directly access SLEPC through a url, only if already logged in. 2.1.1.1.3 The platform should request the user to log in if not.
	<u>2.2 Main page</u>			
		2.2.1 Onboarding		
			2.2.1.1 As a user, the first time I open the Web Platform, I want to receive an introduction to how it works.	
				2.2.1.1.1 - An introduction to how the web application works is displayed the first time the web application is launched. 2.2.1.1.2 - The introduction to how the web application works is not displayed when the web application is launched subsequently. 2.2.1.1.3 - The explanatory content is available to web application users in the respective functional areas.

		2.2.1.2 As a user, I want the app to be displayed in English, so that I can understand how to use the app.	
			2.2.1.2.1 The configured system language is set in English by default
	2.2.2 Information and Instructions for Using the App		
		2.2.2.1 As a user, I want to have access to a FAQ list, so that I can find answers to questions I might have about the app.	
			2.2.2.1.1 The web application will either contain a link to a web page with FAQs, which is displayed in a browser window, or the web page will be displayed within the app itself.
		2.2.2.2 As a user, I want to have access to instructions, so that I can understand the app and its functions.	
			2.2.2.2.1 An explanation of the app's various functions will be provided.
	2.2.3 Adding a building		
		2.2.3.1 The user would like to access the assigned building that the EPC assessor created.	
			2.2.3.1.1 The user should be able to find a user id easily to provide to the EPC assessor.
			2.2.3.1.2 The user should be able to create an account by an email provided from the EPC assessor, if a user id is not available.
	2.2.4 Building list sorting		

		2.2.4.1 As a user, I want to sort the buildings as it suits me	
			2.2.4.1.1 The user should be able to sort the buildings by date, by name, by stage etch.
	2.2.5 Database		
		2.2.5.1 As a user, I want all the file of the studies gathered in one digital point	
			2.2.5.1.1 A database should be developed
2.3 Dynamic			
	2.3.1 Data Access		
		2.3.1.1 As a user, I want to be able to view my buildings measurements	
			2.3.1.1.1 The user should be able to view the measured values of the building depending on the sensor and measurement.
			2.3.1.1.2 The platform should provide the appropriate visualization of the data.
	2.3.2 Dynamic Model		
		2.3.2.1 As a user I want to view the measurements directly to my building.	
			2.3.2.1.1 The platform should provide a 3D visual representation of the user's building with different views of the measured data.
2.4 Assessment Results			
	2.4.1 Result visualization		
		2.4.1.1 As a User, I want some graphs that visualize the results	
			2.4.1.1.1 Results should also be visualized as graphs
	2.4.2 Statistics		

		2.4.2.1 As a User, I want statistics exportation that derived from the results so I will be able to compare my studies	
			2.4.2.1.1 Some statistics should be exported from the results
			4.3.2.1.2 Statistics from the current building should be compared with statistics from other building studies
	2.4.3 Assessments		
		2.4.3.1 As a user, I want to store/access my assessments in the platform.	
			2.4.3.1.1 The platform should be able to store completed assessments in the database (CIEM).
		2.4.3.2 As a user, I want to export/print/share my resulting EPC directly from the platform.	
			2.4.3.2.1 The platform should be provide the user the option to export/print/share the certificate.
2.5 Accesses			
	2.5.1 Access to the EPC Assessor		
		2.5.1.1 As a User, I want to give access for my building to an engineer, so he/she can issue a certificate without filling any parameters	
			2.5.1.1.1 The user should be able to give access to the assessor.
	2.5.2 Access to all building files		
		2.5.2.1 As a User, I want to have access to all files that are related to my building.	

				2.5.2.1.1 The user should be able to export files to their device. 2.5.2.1.1 The platform should be able to export different types of file formats.
			2.5.2.2 As a user, I want to give permission to the Authorities to access my assessment/certificate.	
				2.5.2.2.1 The user should be able to give access to the authorities after they send a request.
	2.6 Digital Building Logbook			
		2.6.1 Digital Building Logbook functionality		
			2.6.1.1 As a user, I want to view my Building Unit's Record.	
				2.6.1.1.1 The platform should keep a record of the changes made in the building. (DBL)
3. Public Database				
	3.1 Neighborhood Level			
		3.1.1 Neighborhood monitoring		
			3.1.1.1 As a user, I want to be able to view the publically available data regarding the neighborhood.	
				3.1.1.1.1 The website should have a page with the publically available data. 3.1.1.1.2 The user should easily find the page in the home page. 3.1.1.1.3 The user cannot alter data.

		3.1.2 User's Buildings		
			3.1.2.1 As a user, I want to be able to search my building in the neighborhood.	
				3.1.2.1.1 The user should be able to search their building using a building id or address 3.1.2.1.2 The platform should have a separate page for the public available building data. 3.1.2.1.3 The platform should have a search function.
	3.2 Unit Level			
		3.2.1 Benchmarking		
			3.2.1.1 As a user I want to search and view other building's Performance and compare them to mine.	
				3.2.1.1.1 The user should be able to select and view neighborhood buildings. 3.2.1.1.2 The platform should allow only the public available buildings/building data to be viewed. 3.2.1.1.3 The platform should protect the private data. 3.2.1.1.4 The user cannot alter data.
3. Account Deletion				
	3.1 Delete Account and Unsubscribe			
		3.1.1 Delete Account and Unsubscribe		
			3.1.1.1 As a User I want to be able to delete my SLEPC account and remove my data	
				3.1.1.1.1 An option for deleting an account should be provided to User

				3.1.1.1.2 A link for confirming the deleting should be created
		3.1.1.2. As a User I want to unsubscribe from the email list		
				3.1.1.2.1 If the User wants to delete his/her account a page should be popped up for unsubscribing from emails lists

Authority

Phase	Sub-phase	Epic	Story	Success Criterion
1.Account Creation				
	1.1 Registration / First Login			
		1.1.1 User needs to register to the platform using an e-mail through a secure approach		
			1.1.1.1 User wants to insert e-mail and password to register	
				1.1.1.1.1 The user should have easy to understand fields to insert e-mail and password and press register
				1.1.1.1.2 The user should not be allowed to continue if the fields are empty.
			1.1.1.2 User wants advanced security upon registration	
				1.1.1.2.1 The user should be informed if the e-mail is not correct and not

			allowed to continue. 1.1.1.2.2 The user should be given a second field to verify the password. If the password is not the same with the above, the user should not be allowed to continue 1.1.1.2.3 The user should check that he/she has read terms and conditions and agrees to them. 1.1.1.2.4 The user should be informed after pressing register that the registration is successful and an activation link has been sent 1.1.1.2.5 Software is designed within Security and Policy by Design principles and guides. The user should be able to read at any given time the Privacy Statement
	1.1.2 User needs to verify his/her e-mail		
		1.1.2.1 The user wants to receive an e-mail to verify his/her e-mail before gaining access to the platform	

			1.1.2.1.1 The user receives automatically an e-mail which includes a brief explanation and an activation link
			1.1.2.1.2 The user can click the link, open in a browser a SLEPC page and see a notification that his/her account is successfully activated
			1.1.2.1.3 The user should be notified that the activation link is temporary and needs to activate within a certain time after receiving the e-mail
			1.1.2.1.4 The user will be informed that the account is not activated and cannot login if he/she hasn't pressed their activation link sent to them
	1.1.3 User needs to first login and set profile		
		1.1.3.1 The user wants to login and set up a profile on first login including mandatory and optional fields	
			1.1.3.1.1 The user will be able to login right after activating the account

				1.1.3.1.2 The user will be guided to a page to set his/her profile
				1.1.3.1.3 The user should insert Name, Surname, Profession (drop down), type of user (drop down), and a few more mandatory fields. The user should not be able to proceed if the profile is not completed
			1.1.3.2 The user wants to link social media	
				1.1.3.2.1 The user should be able to link Twitter and LinkedIn to his/her profile for publishing results or other information
			1.1.3.3 The user wants to do use SLEPC Account Management either from a PC or a mobile device	
				1.1.3.3.1 All pages should be responsive and functional either through PC or a mobile device
				1.1.3.3.2 All pages should be operational in all known browsers (Firefox, Chrome, Opera, Edge, Safari)
	1.2 Profile Management			
		1.2.1 Profile modification		

			1.2.1.1 The user wants at any given time to be able to change their profile	
				1.2.1.1.1 The user can click on their profile and change at once most of their information and click save/update
2.Application				
	2.1 SLEPC Plartform			
		2.1.1 Open the SLE Web Platform		
			2.1.1.1 The user would like to open the SLE Web Platform	
				2.1.1.1.1 The user is able to open SLE Web Plaform throught the SLEPC page. 2.1.1.1.2 The user is able to directly access SLEPC through a url, only if already logged in. 2.1.1.1.3 The platform should request the user to log in if not.
	2.2 Main page			
		2.2.1 Onboarding		
			2.2.1.1 As a user, the first time I open the Web Platform, I want to receive an introduction to how it works.	
				2.2.1.1.1 - An introduction to how the web application works is displayed the first time the

			web application is launched. 2.2.1.1.2 - The introduction to how the web application works is not displayed when the web application is launched subsequently. 2.2.1.1.3 - The explanatory content is available to web application users in the respective functional areas.
		2.2.1.2 As a user, I want the app to be displayed in English, so that I can understand how to use the app.	
			2.2.1.2.1 The configured system language is set in English by default
	2.2.2 Information and Instructions for Using the App		
		2.2.2.1 As a user, I want to have access to a FAQ list, so that I can find answers to questions I might have about the app.	
			2.2.2.1.1 The web application will either contain a link to a web page with FAQs, which is displayed in a browser window, or the web page

				will be displayed within the app itself.
			2.2.2.2 As a user, I want to have access to instructions, so that I can understand the app and its functions.	
				2.2.2.2.1 An explanation of the app's various functions will be provided.
	2.3 Registered Building Units/Complexes			
		2.3.1 Building unit/complex list		
			2.3.1.1 As a user, I want to have a viewing page of the registered building units/complexes	
				2.3.1.1.1 The user should be able to view the database of the registered building units/complexes in an orderly fashion.
			2.3.1.2 As a user, I want to sort the buildings as it suits me	
				2.3.1.2.1 The user should be able to sort the buildings by date, by name, by stage, by id etc.
			2.3.1.3 As user, I want to view information of a	

			building unit/complex	
				2.3.1.3.1 The user should be able to find a building using an id registered to the building unit/complex.
				2.3.1.3.2 There should be a search function using the building unit/complex id/name/address.
		2.3.2 Database		
			2.3.2.1 As a user, I want all the file of the studies gathered in one digital point	
				2.3.2.1.1 A database should be developed
	2.4 Assessment Results			
		2.4.1 Result visualization		
			2.4.1.1 As a User, I want some graphs that visualize the results	
				2.4.1.1.1 Results should also be visualized as graphs
		2.4.2 Statistics		
			2.4.2.1 As a User, I want statistics exportation that derived from the results so I will be able to compare my studies	
				2.4.2.1.1 Some statistics should be exported from the results

				2.4.2.1.2 Statistics from the current building should be compared with statistics from other building studies
		2.4.3 Assessments		
			2.4.3.1 As a user, I want to view the assessments of the selected building in the platform.	
				2.4.3.1.1 The platform should be able to store completed assessments in the database (CIEM).
			2.4.3.2 As a user, I want to export/print/share the resulting EPCs directly from the platform.	
				2.4.3.2.1 The user should not be able to view/download the assessment without the permission of the building unit/complex owner or epc assessor.
				2.4.3.2.2 The user should be able to request access to the assessment.
	2.5 Accesses			
		2.5.1 Access to the EPC Assessor		
			2.5.1.1 As a User, I want to give access to an	

			engineer, so he/she can issue certificates for building Complexes.	
				2.5.1.1.1 The user should have access to the results
		2.5.2 Access to all building files		
			2.5.2.1 As a User, I want to have access to all files that are related to my building.	
				2.5.2.1.1 The user should be able to export files to their device.
				2.5.2.1.2 The platform should be able to export different types of file formats.
				2.5.2.1.3 The user should not have access to any personal data. Only to the ones that are necessary for the registration of the building unit/complex.
				2.5.2.1.4 The platform should keep personal data secure.
				2.5.2.1.5 The user cannot alter data.
3. Account Deletion				
	<u>3.1 Delete Account and Unsubscribe</u>			
		3.1.1 Delete Account and Unsubscribe		

			3.1.1.1 As a User I want to be able to delete my SLEPC account and remove my data	
				3.1.1.1.1 An option for deleting an account should be provided to User
				3.1.1.1.2 A link for confirming the deleting should be created
			3.1.1.2 As a User I want to unsubscribe from the email list	
				3.1.1.2.1 If the User wants to delete his/her account a page should be popped up for unsubscribing from emails lists

Administrator

Phase	Sub-phase	Epic	Story	Success Criterion
1.Account Creation				
	2.1 Account Management			
		2.1.1 High level access to manage all accounts		
			2.1.1.1 As an admin user I would like to have access to all accounts for deleting, activating, deactivating, re-sending password reset links, and other useful account	

	management thingies	
		2.1.1.1.1 The Admin User has access to all user accounts. The Admin user cannot see confidential information such as passwords. 2.1.1.1.2 The Admin user can activate or deactivate an account (the user will no longer be able to login and should contact the system administrator) 2.1.1.1.3 The Admin user can check to re-send the activation link, or the password reset link to an end-user 2.1.1.1.4 The admin user should be able to delete permanently an account 2.1.1.1.5 The admin user should be able to handle sub-accounts of Enterprise Users, edit, delete, etc. 2.1.1.1.6 The admin user should be able to change access rights to an enterprise account (e.g. team leader vs team member, etc.)
	2.1.1.2 As an admin user I would like to see how many users are currently online, as well as other user-related statistics	
		2.1.1.2.1 The Admin user should be able to see how many people (and who) are currently online

				2.1.1.2.2 The Admin user should be able to have access to Google Analytics
	2.2 Provide Support			
		2.2.1 Support Account Creation		
		2.2.2 Troubleshooting		
2.Application				
	2.1 App Configuration	2.1.1 App Configuration		
			2.1.1.1 As an administrator, I want to be able to configure the parameters and the data forms so I can keep up with the latest updates e.g updates of Energy Efficiency Regulations of Buildings, SRI	
				2.1.1.1.1 The app receives dynamic configurations from the administrator that can affect the methodology
				2.1.1.1.2 Thresholds can be configured depending on the provided API.
			2.1.1.2 As an administrator I want to manage the app content centrally, so that I can update texts, links etc.	
				2.1.1.2.1 Updates will be performed automatically
				2.1.1.2.2 The User will be informed of upcoming updates
	2.2 Technical Support	2.2.1 Technical Support		

		2.2.1.1 As an app user, I want to be able to contact technical support, so that I can resolve any technical problems with the app.	
			2.2.1.1.1 A technical support online chat or a communication form should be available

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Advanced Energy Performance Assessment towards Smart Living in Building and District Level

https://www.SLEPC.eu/en/

https://www.linkedin.com/company/SLEPC/

https://twitter.com/SLEPC

https://www.youtube.com/channel/UC0SKa-20tiSabuwjtYDqRrQ

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