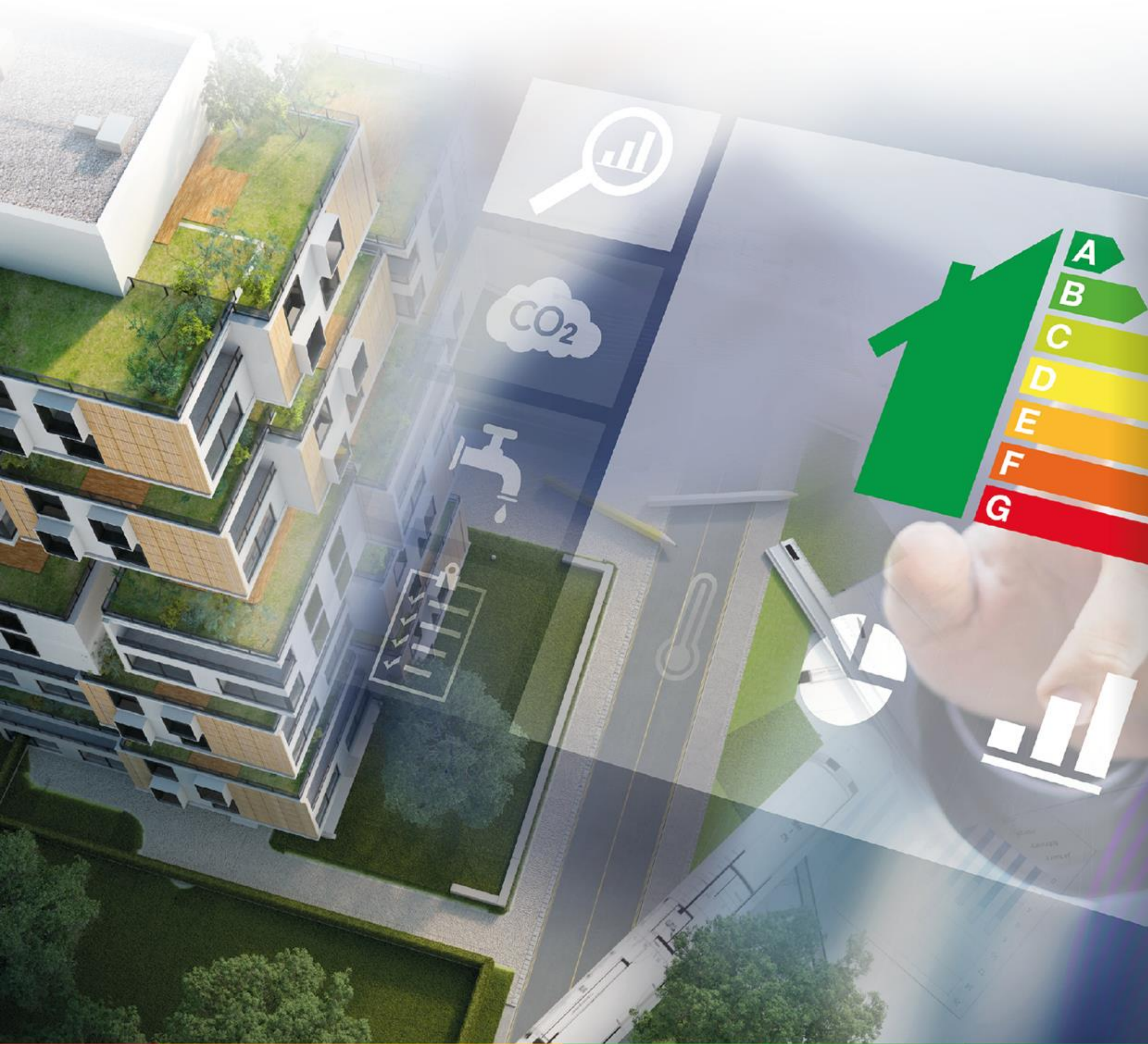
D4.3 EPCs calculation and APIs



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Project Acronym:	SmartLivingEPC
Project Full Title:	Advanced Energy Performance Assessment towards Smart Living in Building and District Level
Grant Agreement:	101069639
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D4.1 SmartLivingEPC CIEM & Building Dynamic Behaviour Monitoring Platform v1

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0.4	Beatriz Fraga De Cal (IES RD)	06/02/2024	Draft version ready for internal review
0.5	Eider Iribar (GOI)	09/02/2024	Internal review
0.6	Beatriz Fraga De Cal (IES RD)	12/02/2024	Updated based on comments from partners
1.0	Aggeliki Veliskaki (CERTH), Nikos Katsaros (CERTH)	15/02/2024	Ready for submission

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Executive Summary

This report describes the work related to the initial development of the Energy Performance Certificates (EPCs) calculation of SmartLivingEPC, as well as the related Application Programming Interfaces (APIs) tailored for integration with third-party applications. The EPCs calculation process relies on the ongoing methodologies produced in Work Packages 2 and 3 for both schemes, Asset and Operational respectively. This computational infrastructure will be an integral part for the final visualization and Internet of Things (IoT) platform of SmartLivingEPC.

Overall, deliverable D4.3 includes first an *Introduction* section that outlines the scope and objectives. Then, the *Methodologies* section that provides an overview of both engines, Asset Rating and Operational Rating. The next section centres on *the EPC calculation* module for the existing components followed by the *Test and Validatio*n chapter, which introduces the first outcomes with current available data at this stage. Concluding this deliverable, a summary of the main development progress of the task is provided along with the next steps to deliver the final SmartLivingEPC platform.

Table of Contents

The SmartLivingEPC project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069639.

The SmartLivingEPC project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069639.

List of Figures

The SmartLivingEPC project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069639.

List of Tables

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List of Acronyms and Abbreviations

Term	Description
API	Application Programming Interfaces
CCT	Correlated Color Temperature
CINEA	Environment Executive Agency
CO_2	Carbon Dioxide
CRI	Color Rendering Index
DHW	Domestic Hot Water
EPC	Energy Performance Certificates
EU	European Union
IEQ	Indoor Environmental quality
IoT	Internet of Things
K	Kelvin
LCA	Lyfe Cycle Assessment
LCC	Life Cycle Cost
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfied
RER	Renewable Energy Ratio
SLEPC	Smart Living EPC
SRI	Smart Readiness Indicators
TVOCs	Total Volatile Organic Compounds
WSM	Weighting Sum Model

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1 Introduction

1.1 Scope

This report presents the current development on the first version of the EPC calculation modules and EPCs calculation and APIs for 3rd party applications.

The EPC calculation stands as a pivotal component towards the final SmartLivingEPC certificate. It´s an essential part for the computation of both engines within the project: Asset and Operational. These engines contribute to the performance building evaluation and their outcomes will be utilized from other components within the SmartLivingEPC framework.

In order to establish the ultimate SmartLivingEPC rating system at both building and complex level, all indicators from WP2 and WP3 shall be combined and correlated. Firstly, the module for the SmartLivingEPC Asset rating system is conducted, which integrates indicators from the SRI analysis, energy and non-energy analyses, and Life Cycle Assessment (LCA). Weighted correlations are also implemented to conclude a unified score. Secondly, the Operational rating engine is described, which considers multiple factors such as energy efficiency, indoor air quality, life cycle analysis, and operational indicators at the building complex level. Preliminary class diagrams for each calculation submodule are also delivered.

Additionally, as part of T4.5 activities, the current progress of the RESTful interface development is presented. The API facilitates third-party applications to retrieve results.

1.2 Objectives

The key objectives that serve as the primary focus of this deliverable are listed below.

- **Comprehensive overview** of SLE methodologies associated with two engines of the platform i.e. the Asset rating and Operational rating certification. This involves an analysis of the existing frameworks in Work Package (WP) 2 and 3.
- Description of the **EPC Calculation** Infrastructure. A detailed explanation of the present calculation development and backend framework for the final EPC platform.
- Test and Validation. First **testing outcomes** from the project's pilot sites. The initial testing is included to provide insights into the practical performance of the methodologies.

1.3 Relation to other Tasks and Deliverables

The development for the first version of the EPC calculation majorly depends on the methodologies defined in WP2 and WP3. Therefore, the main project tasks contributing to the delivery the final version of the Interoperable software prototype are listed below:

- T2.1 SRI analysis and integration to SmartLivingEPC (REHVA)
- T2.2 Energy and non-energy resources analysis and integration to SmartLivingEPC (AIIR)
- T2.3 Environmental life-cycle assessment and integration to SmartLivingEPC (FRC)
- T2.4 Technical audits and inspections integration to SmartLivingEPC (WSEE)
- T2.5 Building complex assessment Asset methodology (UDESUTO)
- T2.6 SmartLivingEPC Asset rating calculation methodology (AIIR)
- T3.1 IEQ (including virus risk mitigation) analysis and integration to SmartLivingEPC (TalTech)
- T3.2 Operational level energy analysis and integration to SmartLivingEPC (FRC)

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- T3.3 Financial indicators and integration to SmartLivingEPC (DEMO)
- T3.4 Building complex assessment operational methodology (UDEUSTO)
- T3.5 SmartLivingEPC Operational rating calculation methodology (FRC)

Additionally, the seamless interoperability between the project´s technologies and the hardware infrastructure is essential to deliver the final SLE Web Platform prototype. Currently, the main focus lies on the development phase of the existing defined methodologies and will continually progress with the final methodologies delivery. Figure 1 shows a general chart mapping those tasks and their interdependencies.

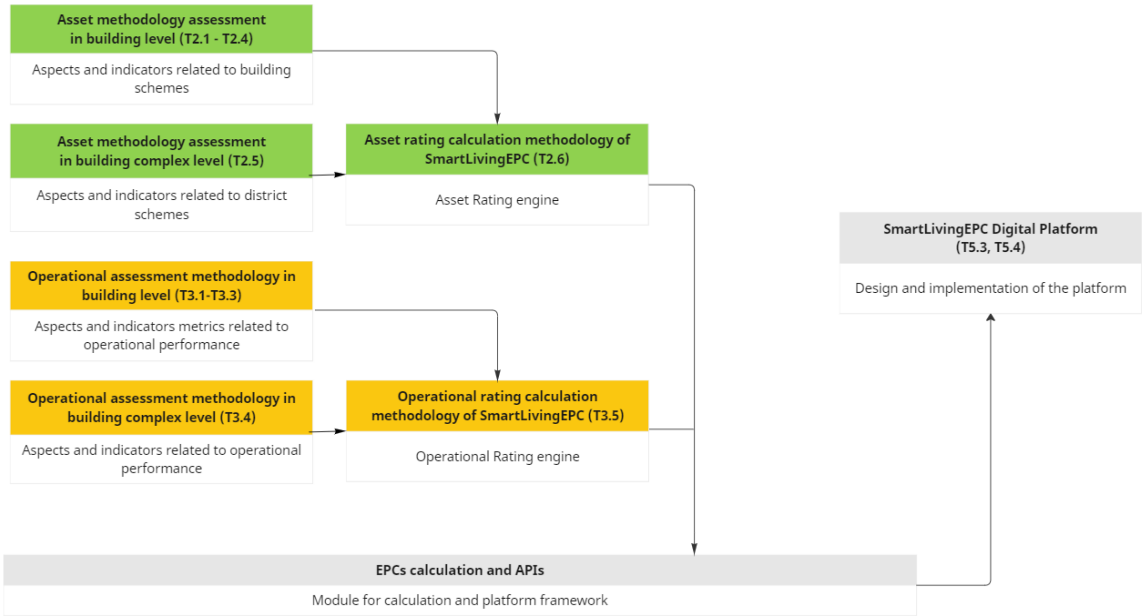

Figure 1. Interconnection between tasks and D4.3

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2 Methodologies

This chapter offers an introduction to the current project methodologies, providing the necessary technical context for understanding the subsequent calculation process detailed in the following section. It describes an overall overview of both final certifications in SLEPC framework. Firstly, the Asset rating methodology is explained based on the existing finding in WP2. Secondly, the current Operational rating is described based on WP3 progress. Both Asset and Operational certifications encompass two scheme levels i.e. building and complex, which are further detailed below.

2.1 Asset Methodology

2.1.1 Building level

The SmartLivingEPC (SLEPC) rating system offers a thorough method for assessing building performance. It focuses **not only on energy efficiency** but also on a wide range of **non-energy factors** that are crucial for guaranteeing the well-being, health, and environmental sustainability of occupants. This approach emphasizes the significance of Indoor Environmental Quality (IEQ), efficiency in utilizing water resources, assessment of radon risk, building integrity in places at risk to earthquakes, and accessibility for those with impairments. The SLEPC rating system provides a comprehensive view of building performance by considering various elements, hence supporting broader sustainability objectives.

Moreover, the proposed rating is characterized by its capacity to be adjusted to the specific requirements of each member state within the European Union (EU). This allows for the evaluation of building energy performance to be matched to local conditions, legislation, and energy sources. The purpose of the SLEPC system is to supplement and improve existing national rating systems by including new layers of assessment, including Smart Readiness Indicators (SRI), non-energy performance metrics, and sustainability indicators.

The SLEPC grading system focuses on differentiating between final energy consumption, which refers to the energy directly utilized by building systems like heating, cooling, and lighting, and primary energy, which encompasses the complete energy lifetime from resource extraction to end-use. Understanding this differentiation is crucial for comprehending the wider ecological consequences of a building's energy consumption. The SLEPC system prioritizes the utilization of national conversion factors to compute primary energy, taking into account the disparities in energy composition, conversion and distribution efficiency, and other specific aspects within different nations. This guarantees that the fundamental energy calculations are precisely adjusted to local circumstances, improving the comparability and significance of the SLEPC ratings.

In addition, the SLEPC grading system examines the renewable energy ratio (RER) as a crucial energy metric, evaluating the utilization of both non-renewable and renewable energy in different building systems. This examination enhances a comprehensive understanding of a building's energy performance, embracing both efficiency and sustainability across various dimensions.

Concerning the indicators, they are split into two groups, energy and non-energy metrics. A short description for all of them is listed below:

a) Non-Energy Indicators

Visual Comfort

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- **Artificial Illuminance Level**: This measures the amount of light provided by artificial lighting sources, impacting the ability to perform tasks comfortably without straining the eyes. Optimal levels depend on the specific activities within a space.
- **Color Rendering Index (CRI)**: CRI measures the ability of a light source to accurately reproduce the colors of various objects in comparison to a natural light source. High CRI values (>80) are preferred in spaces where true color perception is critical.
- **Artificial Lighting Sources Temperature**: This refers to the correlated color temperature (CCT) of lighting, measured in Kelvin (K). CCT affects the perception of space and can influence mood and alertness. Warmer lights (2700K – 3000K) are typically used in residential settings, while cooler temperatures (3500K – 5000K) are common in workspaces.

Acoustic Comfort

- **Sound Pressure Level/Frequency**: This indicator measures the intensity of sound at different frequencies, affecting speech intelligibility and privacy.
- **Global Sound Pressure Level**: This indicator represents the overall level of sound in an environment, impacting the ability to concentrate and communicate effectively.
- **Reverberation Time RT60**: The time it takes for sound to decay by 60 dB in a closed space. Optimal reverberation times vary by room use but are crucial for speech clarity and reducing noise pollution.

Thermal Comfort

- **Operative Temperature**: A combined measure of air temperature and mean radiant temperature, affecting occupant comfort and productivity.
- **PMV Index (Predicted Mean Vote)**: An index that predicts the mean value of the votes of a large group of people on the 7-point thermal sensation scale, indicating how many people are likely to feel too warm or too cold.
- **PPD (Predicted Percentage of Dissatisfied)**: An estimate of the percentage of people likely to feel thermally uncomfortable in a given environment.

Indoor Air Quality

- **CO_2 Level**: High levels of CO_2 can indicate inadequate ventilation and can lead to decreased productivity and increased health risks.
- **Radon Risk Rating**: Radon is a radioactive gas that can enter buildings from the ground. It is a health hazard, and its concentration should be minimized.

Other non-energy Indicators

- **Accessibility Index Rating**: Measures how easily people with disabilities can access and use the building facilities.
- **Water Consumption Efficiency Rating**: Evaluates the efficiency of water use within the building, considering fixtures, fittings, and irrigation.
- **Earthquake Hazard Risk**: Assesses the building's location relative to seismic zones and its structural design's ability to withstand earthquake forces.

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b) Energy indicators

- **Non-Renewable Primary Energy Consumption for the Heating system (Electric vector & Thermal vector).** This indicator measures the amount of primary energy from non-renewable sources consumed by the heating system, differentiated by electric and thermal energy vectors. The electric vector refers to electricity used directly for heating, while the thermal vector includes fuels like natural gas or oil.

- **Renewable Primary Energy Consumption for the Heating system (Electric vector & Thermal vector).** This indicator tracks the primary energy from renewable sources used by the heating system, distinguishing between electric (e.g., solar PV electricity) and thermal vectors (e.g., solar thermal, biomass).

- **Non-Renewable Primary Energy Consumption for the DHW system (Electric vector & Thermal vector).** This measures the primary energy from non-renewable sources consumed by the domestic hot water (DHW) system, including both electricity and direct thermal energy sources.

- **Renewable Primary Energy Consumption for the DHW system (Electric vector & Thermal vector).** This indicator quantifies the renewable primary energy used by the DHW system, split into electric (e.g., wind-generated electricity) and thermal sources (e.g., geothermal heat).

- **Non-Renewable Primary Energy Consumption for the Cooling system (Electric vector & Thermal vector).** It assesses the primary energy from non-renewable sources used for cooling, covering electrically powered systems and any thermal cooling technologies.

- **Renewable Primary Energy Consumption for the Cooling system (Electric vector & Thermal vector)** This tracks the renewable primary energy used for cooling, including both electrically driven and thermal cooling systems powered by renewable sources.

- **Non-Renewable Primary Energy Consumption for the Ventilation system (Electric vector).** This measures the non-renewable primary energy consumed by the ventilation system, focusing on electrically powered components.

- **Renewable Primary Energy Consumption for the Ventilation system (Electric vector).** It quantifies the renewable primary energy used by the ventilation system, specifically through electrically powered mechanisms.

- **Non-Renewable Primary Energy Consumption for the Lighting system (Electric vector).** This indicator assesses the primary energy from non-renewable sources consumed by the lighting system, exclusively considering electric lighting.

- **Renewable Primary Energy Consumption for the Lighting system (Electric vector).** It measures the renewable primary energy used for lighting, focusing on electricity generated from renewable sources.

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- **Non-Renewable Primary Energy Consumption for the BAC system (Electric vector).** This tracks the non-renewable primary energy consumed by the Building Automation and Control (BAC) systems, specifically through electrical energy.

- **Renewable Primary Energy Consumption for the BAC system (Electric vector).** It measures the renewable primary energy used by BAC systems, exclusively considering electrically powered components.

- **Total Non-Renewable Primary Energy Consumption, Thermal vector.** This aggregates the total primary energy from non-renewable sources consumed across all systems, focusing on thermal energy.

- **Total Non-Renewable Primary Energy Consumption, Electric vector.** This sums up the total primary energy from non-renewable sources consumed across all systems, focusing on electrical energy.

- **Total Renewable Primary Energy Consumption, Thermal vector.** This aggregates the total primary energy from renewable sources used across all systems, focusing on thermal energy.

- **Total Renewable Primary Energy Consumption, Electric vector.** This sums up the total primary energy from renewable sources used across all systems, focusing on electrical energy.

- **Building's Energy Performance Class for the Heating system.** This classifies the building's heating system's energy performance, typically ranging from A (most efficient) to G (least efficient).

- **Building's Energy Performance Class for the DHW system.** It classifies the energy performance of the building's domestic hot water system, from A to G.

- **Building's Energy Performance Class for the Cooling system.** This indicates the energy performance classification of the building's cooling system, from A to G.

- **Building's Energy Performance Class for the Ventilation system.** It classifies the energy performance of the building's ventilation system, from A to G.

- **Building's Energy Performance Class for the Lighting system.** This classifies the energy performance of the building's lighting system, from A to G.

- **Building's Energy Overall Performance Class.** It provides an overall energy performance classification for the building, integrating assessments from all systems, from A to G.

- **RER (Renewable Energy Ratio).** This ratio indicates the proportion of total energy consumption met by renewable sources, reflecting the building's sustainability in energy sourcing.

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- **Exported Primary Energy, Electric vector & Thermal vector.** This measures the primary energy exported by the building, distinguishing between electric and thermal energy vectors, indicating the building's contribution to the energy grid or its energy self-sufficiency.

2.1.2 Complex level

The SLEPC project aims to provide energy certificates not only for individual buildings but also to develop a novel rating scheme. This scheme will incorporate the assessment of both individual building units and parameters of building complexes.

D2.2 'Asset assessment methodology in complex level' introduces a set of indicators for assessing a building complex including parameters related to the interaction between buildings. According to the findings presented in D2.2 submitted in M17, the research determined that the sustainability framework at the urban scale could be categorized into three dimensions: environmental, economic, and social, along with an additional institutional dimension. However after extended research and collaboration among partners, an updated set of indicators where defined and documented. Table 1 displays briefly the new version of indicators that carefully revised in order to efficiently cover the SLEPC requirements.

Table 1. Asset Indicators at the neighbourhood scale (updated version of those included in D2.2)

Dimension	Category	Indicator
Environmental	Neighborhood services	**Street Lighting and public area lighting**
		Waste Generation
		Waste Recycling rate
		Wastewater Processing rate
		District Heating System
		District Cooling System
		District Heating Potential
	Renewable Energies	**RES ratio**
		PV ratio
		STC ratio
		GEO ratio
		Potential RES ratio
	Demand Side Management	**DSM - PPA and VPPA contracts**
		DSM - SMI ratio
		DSM - BEMS ratio
		DSM - SMI ratio
		DSM - BEMS ratio
Infrastructure	EV chargers	**EV charger service ratio**
		V2G EV chargers ratio
		EV chargers by building
		Modal Split

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	Mobility and transport	**Fuel Cars ratio**
		EV Cars ratio
		Bike lanes ratio
		Proximity
		Sharing trips availability
		Shared rides ratio
	Neighborhood Building Inventory	**Age of the building stock**
		Renovated 30-year-old buildings
		SmartLivingEPC Asset Rating
		SmartLivingEPC SRI
		SmartLivingEPC LCA
		SmartLivingEPC Non Energy
Social	Energy poverty	**Debt ratio**
		Low absolute energy expenditure
		High share of energy expenditure in income
		Thermal comfort threshold
	Quality of Life	**Heat Island**
		Air Quality
		Noise

Additional details regarding the indicators, including calculation information and data requirements, will be included in the upcoming version of D2.2, D2.5 scheduled for submission by the end of April.

2.1.3 Asset Rating Calculation Methodology

The SLEPC assessment system utilizes a scoring mechanism to convert basic energy consumption into a comprehensible and comparative energy performance classification. The rating system spans from A to G, with the score serving as a clear criterion for assessing energy efficiency. This grading system plays a crucial role in enabling well-informed decisions on enhancements in energy efficiency, investments, and the formulation of policies. Furthermore, it plays a pivotal part in the worldwide evaluation of buildings by considering energy, non-energy, and environmental variables in addition to SRI values.

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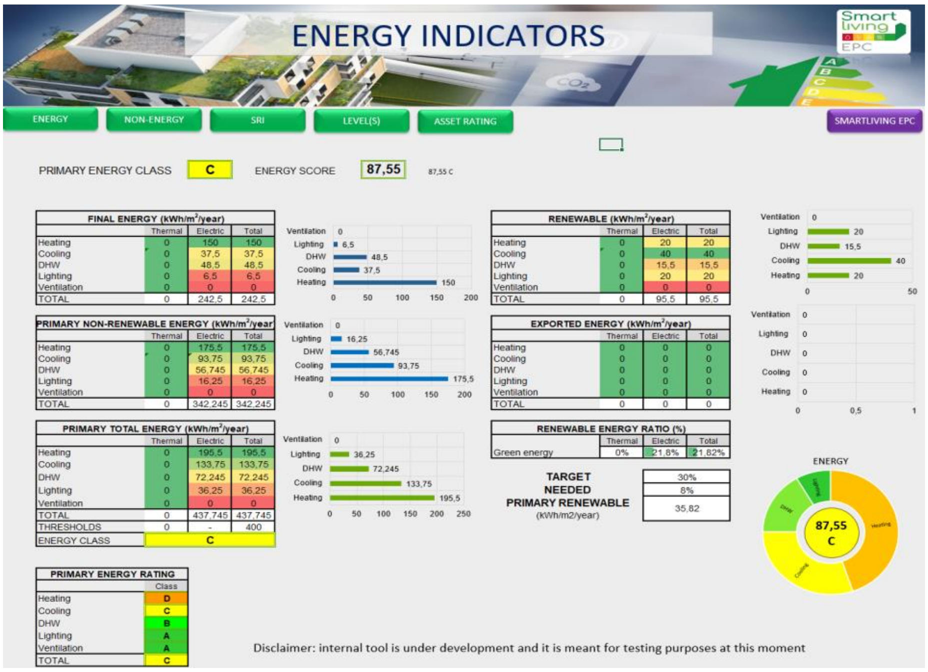

Figure 2. Example of the energy rating assessment procedure (draft version)

The SLEPC system incorporates a zonal approach that recognizes the inherent diversity inside buildings caused by variations in usage and occupant behaviour. This approach entails partitioning a structure into discrete areas with specific attributes and demands, such as levels of noise, air quality, and thermal comfort, to guarantee a precise evaluation. Zonal analysis enables focused interventions by identifying areas for enhancement, hence improving the overall performance of the structure.

The SLEPC rating system utilizes a weighted mechanism to consider the surface size of each zone, guaranteeing that larger regions have a proportionate influence on the final ranking. This methodology permits an equitable and accurate assessment, facilitating efficient distribution of resources and priority according to the importance of each zone. The system's technique involves evaluating many components of Indoor Environmental Quality (IEQ), including indoor air quality, thermal comfort, visual comfort, and acoustic comfort. Each component is assessed using specific indicators and scoring methods.

The assessment of indoor air quality is determined by measuring the levels of carbon dioxide (CO_2) and evaluating the danger of radon exposure. A scoring system is used to assess the effectiveness of ventilation and the potential health risks associated with the air quality. Thermal comfort is evaluated by utilizing the Predicted Mean Vote (PMV) and overheating indicators, which consider seasonal fluctuations and the amount of time interior temperatures above comfort thresholds. The assessment of visual comfort centers around factors such as illuminance, daylight factor, colour rendering, and colour temperature, acknowledging their influence on the productivity and well-being of occupants. Acoustic comfort is assessed by measuring sound pressure levels and reverberation duration, which evaluate the impact of noise on concentration and satisfaction.

In addition, the SLEPC grading system considers accessibility, earthquake vulnerability, and water efficiency, integrating them into the comprehensive performance evaluation. The evaluation of each aspect involves the use of criteria and scoring, which accurately assess their influence on the quality of the building and the safety of its occupants.

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The SLEPC system offers a notable benefit in terms of its versatility, which enables the customization of indicator weighting to accurately represent area vulnerabilities, user preferences, and special building purposes. The adaptability of the rating system allows it to cater to a wide range of demands and preferences, hence increasing its usefulness and efficiency in different situations.

WEIGHTING		
Indicator	Default	User
Indoor air quality	20	
Thermal comfort	15	
Visual comfort	15	
Acoustic comfort	15	
Accesibility	10	
Earthquake seismic class	15	
Water efficiency	10	

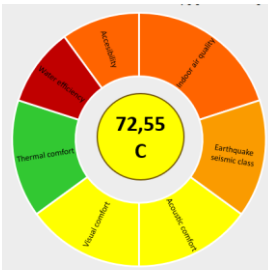

Figure 3. Example of main non-energy indicators and rating

The SLEPC rating system is an innovative method for evaluating building performance. It combines energy and non-energy data to provide a thorough assessment of buildings. The tool's versatility lies in its focus on zonal analysis, weighted scoring, and customized indicators, which may be used to enhance building sustainability, occupant comfort, and minimize environmental impact. The SLEPC system provides a comprehensive framework for improving building quality and promoting sustainable development goals by considering many elements such as indoor environmental quality, structural integrity, and resource efficiency.

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2.2 Operational Methodology

2.2.1 Building Level

The Operational assessment at building level aims at developing a unified approach for operational building performance certificates. The methodology provides a data-driven framework for building assessment and the major aspects evaluated are Indoor Environmental Quality (IEQ) as well incorporating Life Cycle Cost (LCC) analysis, which is aligned with outlined methods below included in D3.1 Operational assessment methodology.

a) T3.1: IEQ analysis (including virus risk mitigation) and integration to SmartLivingEPC.

A comprehensive review of IEQ aspects was submitted in D3.1 using innovative approaches like conducting surveys in buildings to incorporate occupants' perspectives. IEQ indicators were classified into thermal comfort and indoor air quality.

b) T3.2: Operational level energy analysis and integration to SmartLivingEPC.

In regards to the energy analysis, it is established how to integrate operational data and explore the integration of smart sensors and digital twin practices. The indicators are categorised by lighting, heating, cooling, ventilation, energy use for other services and water heating.

c) T3.3: Financial indicators and integration to SmartLivingEPC.

This assessment uses LCC methodology and evaluates the overall costs of a building asset over its life span. The new EPC classification rating will include not only the total cost, but also the cost per energy use/energy carrier per square meter per month/year as covering as-designed, as-operated and predicted levels.

2.2.2 Complex level

The operational assessment at the complex level aims to establish a unified approach for operational building performance certificates at the neighborhood scale, a development undertaken in T3.4. An initial set of indicators was introduced in D3.2 'Operational assessment methodology in complex level'. As already mentioned, after extensive research of DEUSTO University and contribution from partners, an updated set of indicators was defined. The following table (Table 2: Operational Indicators at the neighbourhood scale (updated version of those included in D3.2) provides a concise overview of the revised indicators, crafted to effectively address the SLEPC requirements.

Table 2: Operational Indicators at the neighbourhood scale (updated version of those included in D3.2)

Dimension	Category	Indicator
Environmental	Neighborhood services	**Street Lighting and public area lighting**
		District Energy Systems Heating
		District Energy Systems Cooling
		Wastewater Treatment Consumption rate
	Renewable Energies	**RES ratio**
Operatory	Neighborhood Building Operatory	**DSM - Load Demand Factor**
		EV Chargers Electricity Consumption rate

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		EV Energy Load
		Buildings (Aggregated energy KPIs)
		Aggregated Heating KPIs
		Aggregated Cooling KPIs
		Aggregated DHW KPIs
		Aggregated Lighting KPIs
		Aggregated Appliances KPIs
		Aggregated GHG KPIs
		SmartLivingEPC Operational Rating
		SmartLivingEPC IEQ
		SmartLivingEPC LCC
		SmartLivingEPC Non-Energy

Further information about the indicators, including calculation details and data prerequisites, will be incorporated into the forthcoming versions of D3.2 and D3.5, planned for submission by the end of March.

2.2.3 Operational Rating Calculation Methodology

The final rating calculation for the Operational assessment has selected 15 indicators out the total 70 included in the initial research. These chosen metrics cover a broad range of aspects coming from the initial assessment: energy consumption, human wellbeing, and Life Cycle Cost (LCC), included in list below and taken from D3.3 and outlines aforementioned indicators.

- **Ventilation Rate (Airflow):** measures the rate at which outdoor air replaces indoor air.
- **Total Volatile Organic Compounds** (TVOCs): key measure of air quality
- **Benzene**: Benzene is a specific VOC known for its harmful health effects.
- **CO_2 indoors**: Indoor CO_2 levels are an indicator of air quality and ventilation effectiveness.
- **Formaldehyde**: As a common indoor air pollutant, its levels are a significant indicator of air quality.
- **Lighting per Floor Area**: reflects the efficiency and design of a building's lighting system.
- **Cooling per Floor Area**: measures the energy efficiency of the cooling systems.
- **Heating per Floor Area**: this indicator assesses the efficiency of heating systems.
- **Energy Use for Appliances per Floor Area**: This metric evaluates the energy efficiency of appliances within the building, an important aspect of overall energy consumption.
- **Energy Use for Domestic Hot Water per Floor Area**: Hot water usage can be a significant energy consumer, especially in residential buildings.
- **Cost per Energy Use per Square Meter per Month/Year**: provides a financial perspective on energy efficiency, translating energy consumption into monetary terms on a monthly and yearly basis.
- **Cost per Energy Carrier per Square Meter per Month/Year**: By breaking down costs by energy carrier.
- **Total Energy Cost per Square Meter per Month**: overall cost burden of energy use, essential for economic assessments and long-term planning.

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The rating methodology also explored different weighting techniques and investigated the principles of the WSM (Weighting Sum Model). It´s a mathematical method for decision-making based on a sum of attributes. Finally, the processing algorithm combines inputs from the user, normalised scores and weights using a weighted sum approach, reflecting stakeholder priorities. This is then translated into score classes (A to G), simplifying interpretation and promoting standardized communication across contexts. Figure 4 depicts the prototype of the operational tool interface.

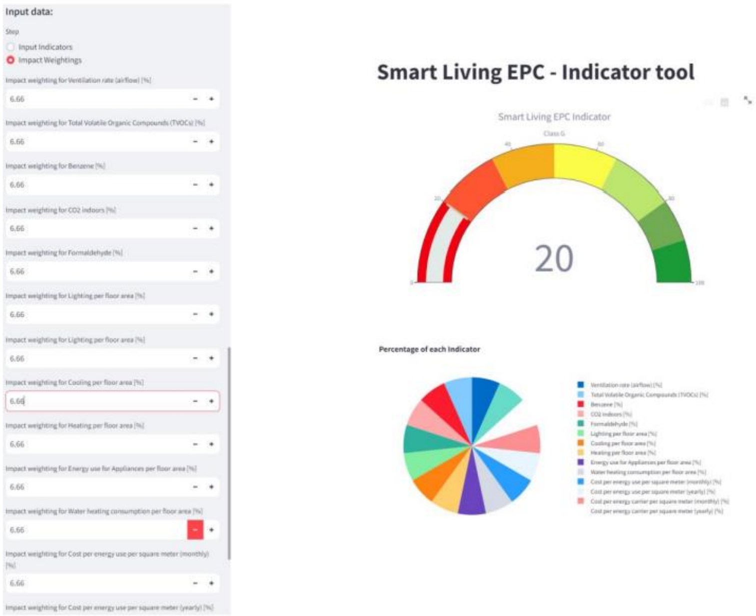

Figure 4. Sample of the engine front end

3 EPC Calculation Module

The calculation engine, as a key element of the SmartLivingEPC framework, is able to perform all necessary computations for an accurate assessment of both asset and operational performance. The presence of two distinct certification schemes has led to the creation of two separate components, each catering to specific calculations. As presented in Figure 5, the CIEM component provides the Asset rating and the Operational rating engines with the required data. The outputs of both components SmartLivingEPC Web Platform database that feeds the Nudge-ready Performance Benchmarking and Evaluation component, which dynamically assess the buildings' performance.

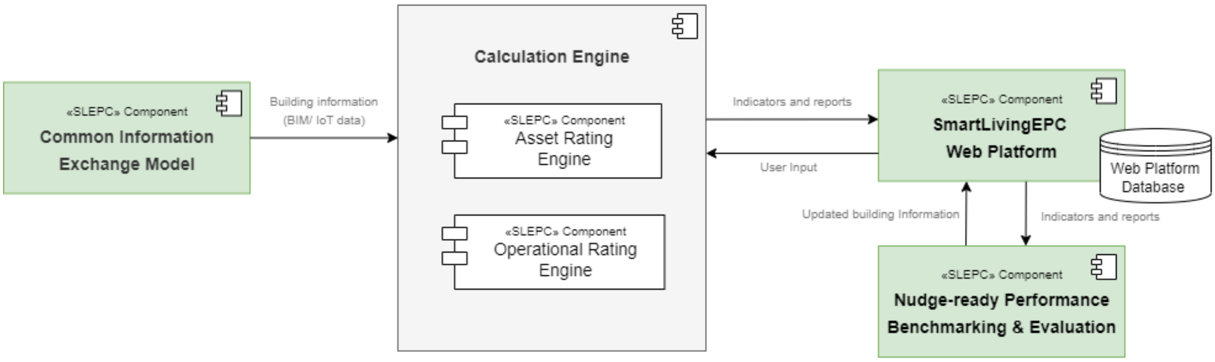

Figure 5. Calculation Engine Functional Diagram

3.1 Asset Rating

This engine (Figure 6) involves the development of a rating system designed to evaluate the energy and environmental performance of building units and building complexes. The rating system considers factors such as intelligence, energy efficiency, sustainability, and technical audits during the assessments.

To establish the SmartLivingEPC rating system, indicators from the SRI analysis, energy and non-energy analyses, Life Cycle Assessment (LCA) are combined and correlated, in a weighted manner in order to conclude to a united score. In case that a building unit is part of a building complex, corresponding indicators derived from the building complex assessment are taken into account in the overall rating of the building unit. A notable aspect of the SmartLivingEPC is its evaluation within a BIM environment. This entails extracting as much as possible of the required input data directly from BIM documents. The results generated by the Asset rating engine are stored in the Web Platform database, providing easy access for future utilization (The second version of D1.2 will be updated accordingly).

The SmartLivingEPC project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069639.

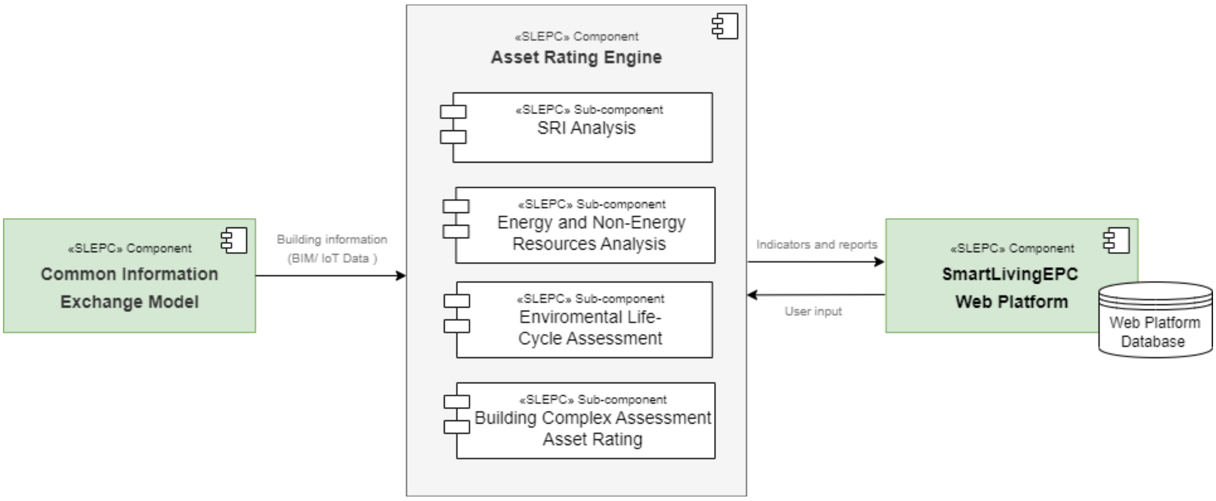

Figure 6. Asset Rating Engine Functional Diagram

3.1.1 Energy indicators calculation

This submodule is responsible for the calculation of the as-designed energy indicators. It requires building-related information as input, which should be provided in a specific JSON format. An example of such input is available in the Annex, and can be retrieved from the appropriate parsing of BIM files. This information is then validated against a minimum set of necessary building parameters, identifying any incorrect or missing values. Following the successful input data verification, the tool iteratively extracts and examines the building's thermal zones, the technical systems, the spaces and the building envelope elements.

The asset-based energy indicators calculation submodule has been developed in a fully object-oriented approach, using Python 3.9 and the following packages:

- Pandas 2.2.0[1]
- Geopy 2.4.1[2]

Figure 7 displays the submodule's class diagram, grouping the main object classes that are utilized in each part of the calculation process. The energy analysis is initiated with the monthly analytical determination of the energy exchange in each thermal zone, in order to determine the corresponding heating and cooling demand. This process includes the calculation of the transmission and ventilation thermal energy exchange, as well as, the internal and solar heat gains, and their weighted summation. Following next, the DHW needs for each thermal zone are identified based on the requirements of the respective boundary conditions. Similarly, the lighting energy demand per thermal zone is calculated. On the other hand, any on-site building energy production is also taken into consideration, e.g. from a PV or solar thermal installation.

Based on the aforementioned energy demand values, the final energy is calculated by matching the energy demand per service with the technical system of each thermal zone, in order to estimate its expected energy consumption. Finally, the primary energy is calculated based on the final energy values and the primary energy factors that correspond to each energy carrier.

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

[2] https://geopy.readthedocs.io/en/stable/

The SmartLivingEPC project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069639.

Within the entire aforementioned process, a number of predefined conditional parameters is utilized, which concerns the indoor/outdoor environment as well as other calculation-dependent information. These can be grouped in the following distinct categories:

- **Climatic data**: Solar radiation and average external temperature time series are considered necessary for the internal calculations. Such information has been extracted from various sources, both open-source and commercial ones, and concerns the climatic zone where the building resides, according to technical directives at a national level.
- **Energy carrier data**: Primary energy factors, which regard each energy carrier per European country and are required to convert delivered energy to primary energy, have also been retrieved from national EPC methodologies.
- **Thermal zones' boundary conditions:** Several parameters related to the indoor environment conditions in each thermal zone are vital for describing their corresponding operating schedule, the heating and cooling demand, and the ventilation and lighting requirements. Such values can also be differentiated at national level and thus are integrated into the tool as country-specific datasets.

The SmartLivingEPC project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069639.

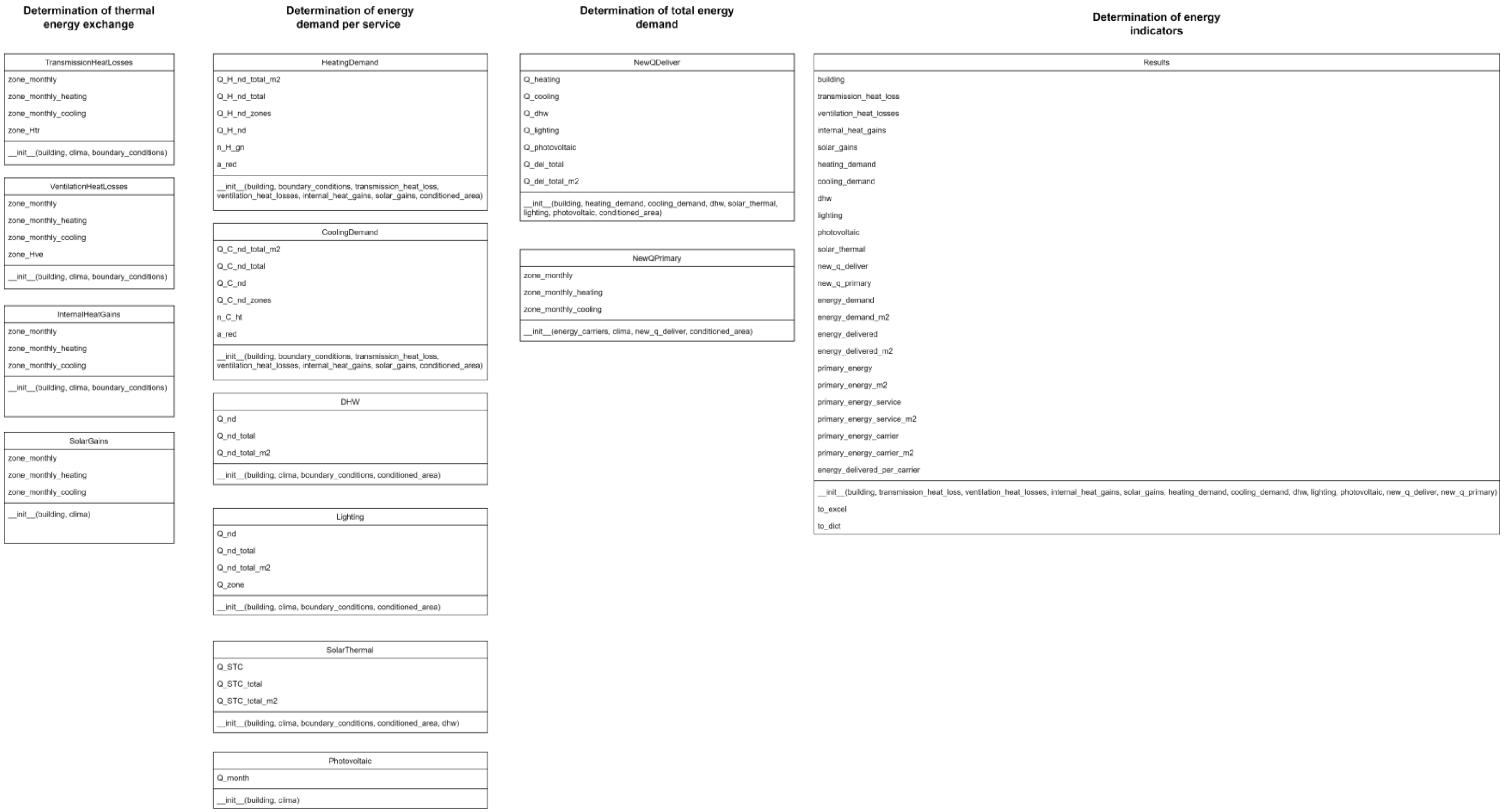

Figure 7. Asset-based energy indicators calculation class diagram

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3.1.2 Non-energy indicators calculation

Figure 8 displays the preliminary class diagram of the non-energy indicators calculation submodule. An object class corresponds to each indicator category and instantiated class objects are assigned to each building zone that is being studied. The zone attribute in each class is an object that embeds all the parameters necessary for the calculations, such as the geometry and the underlying elements, e.g. windows. It is populated using the same building static information input as in the case of the energy indicators calculation submodule.

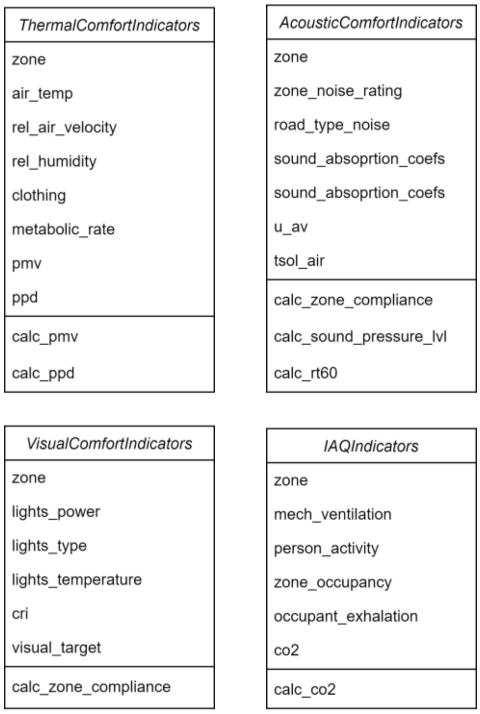

Figure 8. Non-energy indicators calculation submodule class diagram

3.1.3 SRI calculation

This submodule undertakes the calculation of the indicators per the SRI framework, as detailed in Section 3.1.6. The latest version of the *SRI assessment package*[3] is utilized as a basis to develop the software component in a fully object-oriented approach in Python, mainly taking advantage of the Pandas package. To this end, the main class diagrams are presented in Figure 9 and Figure 10 below.

The first object that is instantiated is the *SRIAssessor*. It embeds basic informative parameters related to the person that performs the SRI assessment and are added to the generated report. On the other side, the *SRIBuilding* constitutes the core object class, which integrates building characteristics that are relevant to the calculation, e.g. its type, usage, useful area etc., as well as several other variables and function methods that concern the setup, calculation and processing of the assessment results. To this end, the *domains*class attribute is a list of objects, with each one corresponding to an assessment

[3] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator_en

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domain class (*HeatingDomain…DHWDomain).* All such classes inherit the *SRIDomain* class, which contains the base attributes and methods for representing each domain's calculations and results. In turn, the *domain_services* attribute of the domain objects is a list of objects that correspond to the assessment services of the specific domain (Figure 10) for the building under study. Similarly to the assessment domain classes, each service class inherits the base *SRIService*class, which provides the variables and the functions for appropriate setup.

Finally, a*SRIBuilding*object also includes a *factors* attribute, which corresponds to an *SRIWeightingFactors* object. The latter provides all the necessary static weightings that are used for the calculations, based on the building type and climate zone.

The SRI submodule accepts data inputs in a specific JSON format, an example of which is provided in the Annex.

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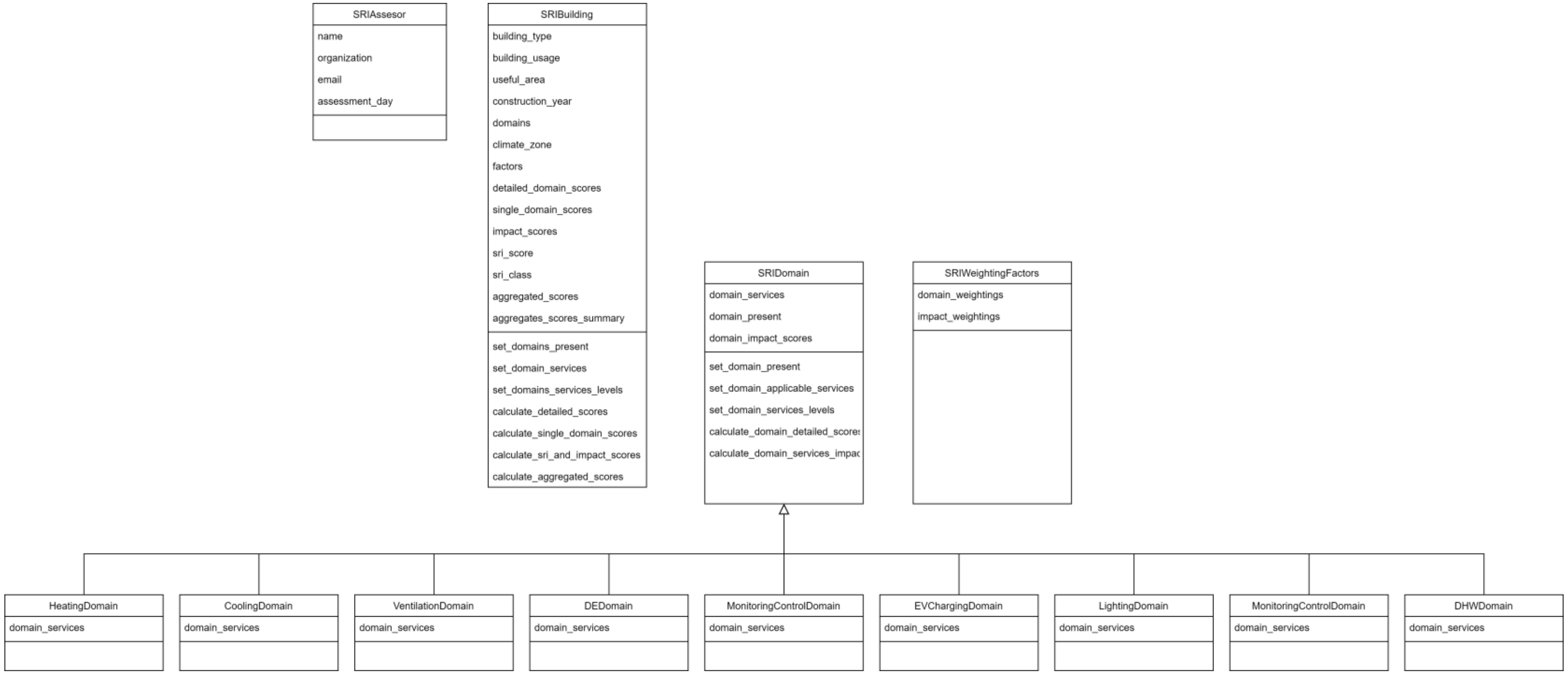

Figure 9. SRI calculation class diagram (1)

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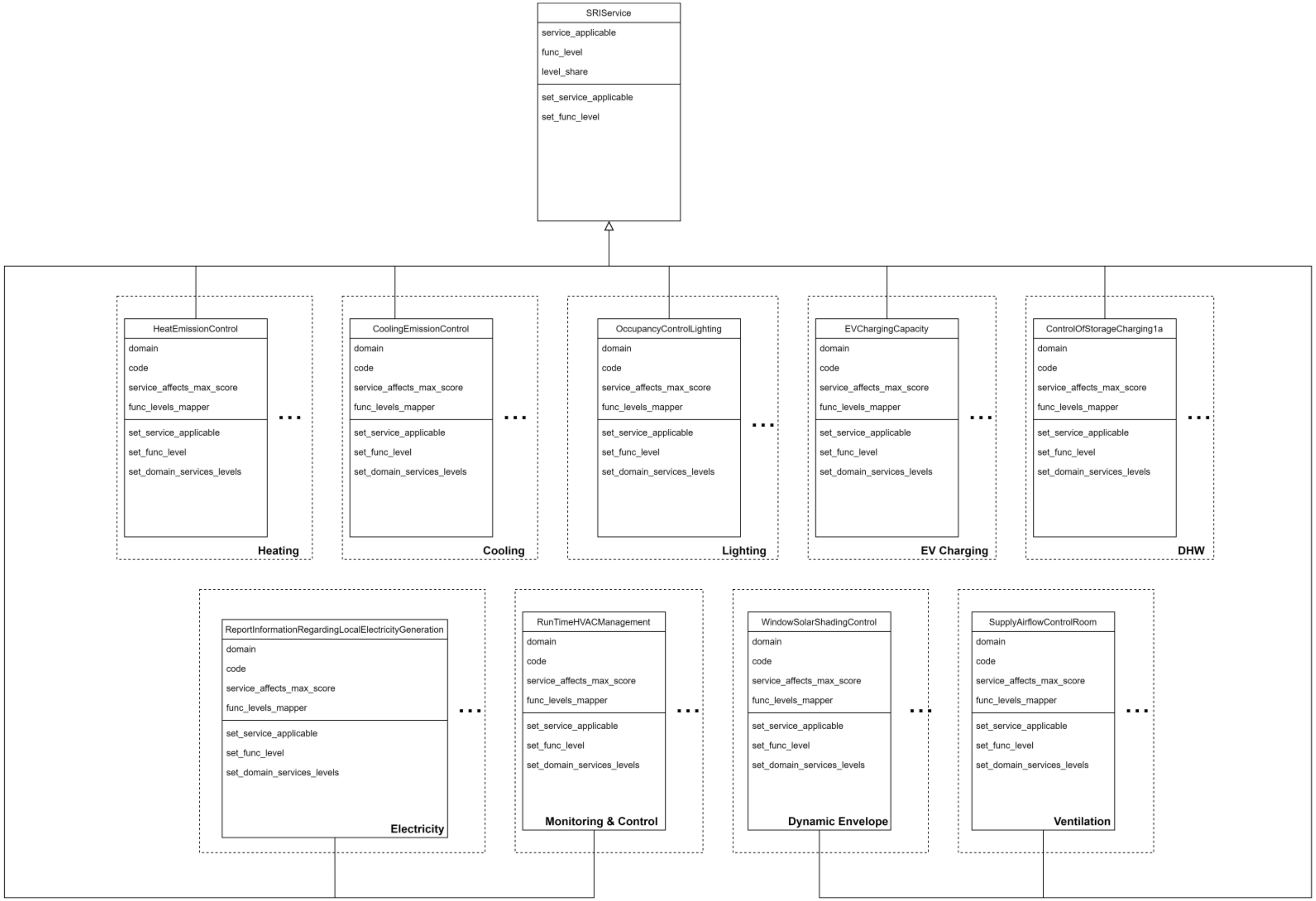

Figure 10. SRI calculation class diagram (2)

The SmartLivingEPC project has received funding from the European Union's
Horizon Europe research and innovation programme under grant agreement No

3.1.4 Environmental LCA indicators calculation

The objective of the SmartLivingEPC initiative is to include a wide range of indicators related to building environmental factors. This effort highlights the importance of integrating Life Cycle Assessment (LCA) techniques into the effective energy planning of buildings. The development of environmental indicators for SmartLivingEPC is based on the Level(s)[4] framework, which acts as the European Union's structure for evaluating and documenting the sustainability performance of buildings throughout their entire life cycle. The Level(s) methodology aligns its assessments with European sustainability goals and utilizes established standards, offering a unified platform for measuring, examining, and understanding the life cycle of buildings.

The first version of the operational rating scheme was presented in D2.1 'Asset methodology assessment in building level' submitted in M13.

Based on D2.1, the LCA sub-component will be developed by FRC along with a corresponding SRI parser for covering its data requirements, and will be integrated into SmartLivingEPC Web Platform through an API. Further information regarding the development of this sub-component will be provided in D2.4 which is the 2nd version of D2.1, planned to be submitted by M20.

3.1.5 Asset-based performance assessment at building unit level

The SmartLivingEPC Asset rating engine aims to cover various aspects of a building's performance, including energy efficiency, environmental impact, and readiness for smart technology. It was designed to be user-friendly and informative, giving a complete picture of the building's features and performance.

The initial draft version of the rating calculation methodology was developed and submitted in D2.3 Asset rating calculation methodology of SmartLivingEPC v1 in M18. Based on D2.3, a general plan for its development was outlined; however, the actual development will be based on the second version of the same deliverable. This will ensure the robustness and accuracy of the new rating scheme to be integrated into the SmartLivingEPC Platform.

The development of the module will adhere to the overall project approach, presented also in previous sections of the document. The chosen design philosophy will facilitate its operation both independently and when integrated into the platform. The input data for the calculation engine will be derived from SmartLivingEPC CIEM repository in a predefined data model format for building units and building complexes accordingly. The output data of the engine will also be stored in the SmartLivingEPC CIEM Repository, accessible to users through the web platform module. Moreover, integration into the SmartLivingEPC platform will allow other components such as nudge-ready performance benchmarking & evaluation tool to utilize the module, requesting customized energy simulations to assess the energy impact of different renovation actions. Python (3.9) will serve as the primary programming language for module development, supplemented by Python packages (i.e., Pandas 2.2.0, Numpy 1.26.0) to enhance functionality.

3.1.5.1 Data Flow

Based on D2.3, the SmartLivingEPC Asset rating engine will retrieve data from the CIEM repository (as shown in Figure 11) through HTTP request. The retrieved data will consist of calculated indicators from

[4] https://environment.ec.europa.eu/topics/circular-economy/levels_en

The SmartLivingEPC project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069639.

energy and non-energy analyses, SRI and LCA analyses, and technical audits, with the prerequisite that the assessor has completed the aforementioned calculations. If the assessment is conducted for a building complex, the indicators for all related buildings should be retrieved, along with supplementary data specific to the building complex.

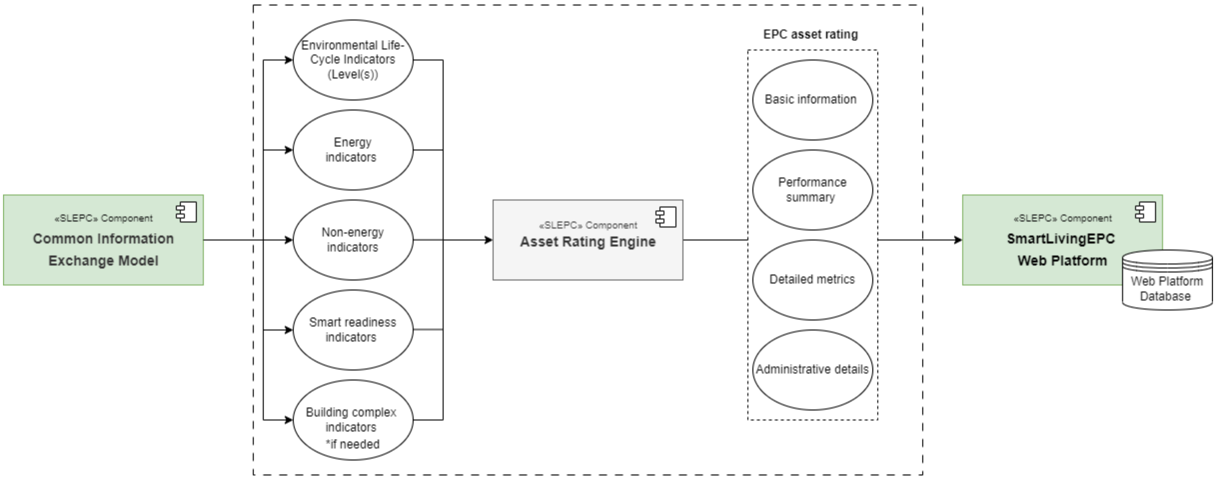

Figure 11. EPC Asset rating information flow

After the completion of the calculations, the output data (i.e., type of building and physical characteristics, climate data, overall rating and sub categories, potential for improvement, energy indicators, environmental indicators, energy and non-energy indicators and administrative details) will be visualized to the end user through the SmartLivingEPC Web Platform and stored in the SmartLivingEPC CIEM repository.

Additional details regarding the actual implementation will be provided in the upcoming version of D4.3 EPCs calculation and APIs, scheduled for release in M24.

3.1.6 Asset-based performance assessment at building complex level

This component aims to introduce a rating scheme for assessing the asset-based performance of building complexes, based on the assessment of individual building units and additional building complex parameters.

The initial draft version of the methodology was presented in D2.2 'Asset assessment methodology in building complex level', submitted in M17. Several alterations and improvements have been implemented so far, so the development will be based in the second version of the same deliverable, planned to be submitted in M22.

Based on D2.2, the first step of the assessment involves selecting the neighborhood area. This will be implemented in the Web Platform using an open-source JavaScript library for mobile-friendly interactive maps called Leaflet5 as illustrated in Figure 12 .

[5] https://leafletjs.com

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Figure 12. Example of area selection

The development of the component will adhere to the overall project approach, and will be presented in detail in the next version of D4.3.

3.2 Operational rating

The Operational rating engine as presented in Figure 13, takes into account various factors, including energy efficiencies, indoor air quality, life cycle analysis, and the assessment of operational indicators at the level of building complexes. The Operational rating engine relies on measured energy amounts, as defined in the 52000-standard series, providing more precise outcomes in contradiction with the Asset rating engine since it is based on actual energy usage and measurements of the under-study building. The required IoT data are retrieved from CIEM database and external APIs (e.g., weather data) and the outcome of the component are stored in SmartLivingEPC Web Platform database for additional utilization from other components within SmartLivingEPC framework.

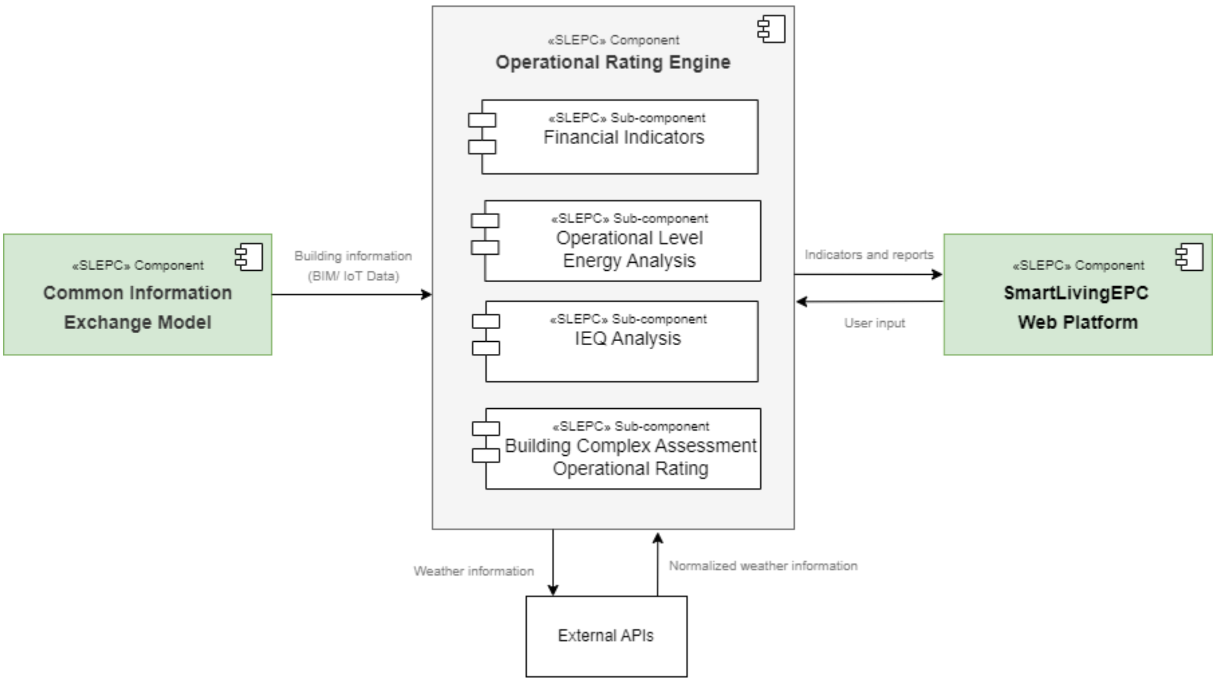

Figure 13. Operational Rating Engine

3.2.1 Energy indicators calculation

This Python software package calculates the as-operated building energy indicators. The following inputs are required:

- Building-related information, which should be provided in the dedicated JSON format that was described in Section 3.1.1. Parameters such as the building location (country, specific coordinates, altitude) as well as its category and usage type are retrieved.
- Historical energy measurements for a complete year, with a minimum daily temporal resolution. This provided input should also follow a specific JSON format, which indicates the unique ID and type of the device providing the measurement, the measurement value and unit and the corresponding timestamp. An example of such input is provided in the Annex. It is important to highlight that the aforementioned device IDs should be included as entries in the building parameters input to allow the spatial allocation of the device in the building model and the retrieval of necessary parameters, such as the corresponding spaces' area, volume etc.

The supported device types are in alignment with the *IfcFlowMeterTypeEnum*[6]and *IfcSensorTypeEnum*[7] of the IFC specification[8].

The class diagram of the operation-based energy indicators calculation submodule is depicted in Figure 14. The *EnergyMeasurementVector* class corresponds to the basic pre-processing of each energy measuring device and includes all the attributes that describe it, i.e. its name, its collected measurements, the spaces that the measurements refer to along with their total area and volume, the energy carrier and the energy services that are provided. On the other side, the *AggregatedEnergyVectors*class gathers objects instantiated from the aforementioned class in order to perform the energy indicators calculation. To this end, it additionally requires attributes related to the overall building, i.e. building total area, volume, occupants and occupancy-hours.

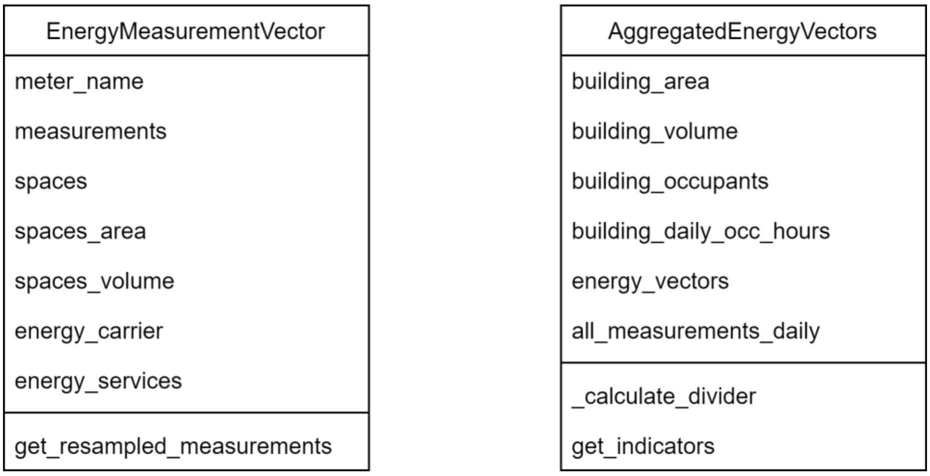

Figure 14. Operation-based energy indicators calculation submodule class diagram

[6] https://standards.buildingsmart.org/IFC/RELEASE/IFC4_3/HTML/lexical/IfcFlowMeterTypeEnum.htm

[7] https://standards.buildingsmart.org/IFC/RELEASE/IFC4_3/HTML/lexical/IfcSensorTypeEnum.htm

[8] https://technical.buildingsmart.org/standards/ifc/ifc-schema-specifications/

3.2.2 Financial indicators calculation

This submodule has been developed in Python and is responsible for the calculation of the defined financial indicators i.e. the as-designed, the as-operated and the as-predicted energy costs. It accepts the same inputs as the Energy indicator calculation submodule of the previous section, i.e. the building-related information and historical energy measurements in the indicated JSON format. However, it additionally requires the corresponding energy pricing scheme i.e. monthly prices per kWh for each used energy carrier, which should follow the exemplary scheme provided in the Annex. Figure 15 displays the module's class diagram. The *GenericCosts* class provides the base attributes and function methods to pre-pre-process input energy data and calculate the building energy costs. Two child classes inherit this class, calculating the as-designed and as-operated costs by providing output data from the asset-based and operation-based indicators calculation submodules, respectively. On the other side, the *AsPredictedCosts* class undertakes the setup and calculation of the nominal cost and the net present value on a 10-year horizon.

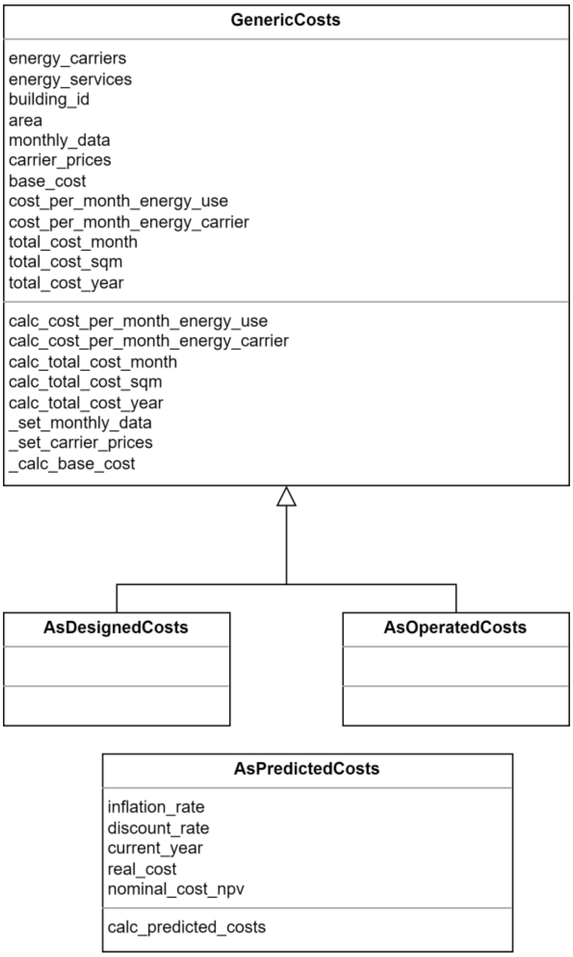

Figure 15. Financial indicators calculation submodule class diagram

3.2.3 IEQ indicators calculation

The preliminary class diagram of the IEQ indicator calculation submodule is provided in Figure 16. A single class has been designed, which aggregates the available historical measurements in building spaces (CO_2, PM2.5, temperature, humidity) as well as in the exterior environment (temperature, humidity, CO_2, PM2.5). The integrated function methods are then responsible for calculating the corresponding indoor air quality, thermal comfort and virus risk indicators.

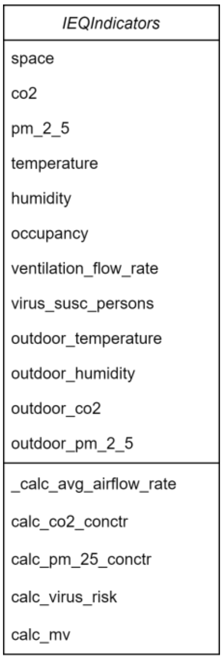

Figure 16. IEQ indicators calculation submodule class diagram

3.2.4 Operation-based performance assessment at building unit level

The operational rating engine aims to incorporate the operational aspects of buildings, integrating enriched data concerning their lifecycle and intelligence. This approach focuses on the well-being of building occupants, ensuring that buildings are not only energy-efficient but also conducive to providing healthy and comfortable living and working environments.

The first version of the operational rating scheme was presented in D3.3-Operational rating calculation methodology of SmartLivingEPC submitted in M18.

Based on sub-section 5.1-Definition and purpose of API in the context of calculating indicators building of D3.3, this engine will be provided as external component and will be reached through an API. Thorough information about the integration of operational rating engine in SmartLivingEPC Web Platform will be available in the forthcoming release of D4.3 EPCs calculation and APIs, in M24.

3.2.5 Operation-based performance assessment at building complex level

This component aims to establish a rating system for evaluating the operational performance of building complexes. It relies on the indicators derived from the operational assessment of individual building units and additional parameters specific to the building complex.

The initial version of the methodology was outlined in D3.2-Operational assessment methodology at the building complex level, submitted in M17. Due to subsequent revisions and enhancements

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implemented in the methodology, the development will be based on the second version of the aforementioned deliverable.

The development will follow the guidelines presented in Section 3.1.6.

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3.3 SmartlivingEPC API

A RESTful interface is under development as part of the activities of T4.5. This API enables the execution of the EPC assessment software services described in the previous sections, and the retrieval of results by authenticated third-party applications. The generic access endpoints are structured as follows:

$$\underbrace{\text{https://smartlivingepc.iti.gr/api/v1}}_{URL\ prefix} / \underbrace{asset\_rating}_{Service} / \underbrace{123456abcdefg}_{Building\ unit/complex\ ID} \tag{1}$$

Each request must refer to specific building unit or building complex, determined by a corresponding ID. Additionally, an authentication API key has to be provided along with the request, which is assigned to a registered user that has viewing rights for the building of their interest. Although the API supports the provision of the aforementioned information, along with other user management functionalities, the graphical user interfaces of the SmartLivingEPC Web Platform will provide a more intuitive way to retrieve the necessary parameters. More details on the API access setup through the Web Platform will be provided in the deliverable D5.1 *SmartLivingEPC Digital Platform: Components development, Integration and Acceptance Tests*.

Table 3 below provides a number of API request/response examples for the services that have been developed up to date. Considering the public status of the current report, basic information only is disclosed.

Table 3. Example API requests and corresponding responses

Description	API request/response

Calculate the asset energy indicators	`curl --location`
	`'https://smartlivingepc.iti.gr/api/v1/asset_energy_indicators/BUILDING_ID' \`
	`--header 'X-Api-Key: API_KEY'`

	`{`
	`  "data": {`
	`    "asset_indicators_results": {`
	`      "CO2": {...},`
	`      "CO2_m2": {...},`
	`      "cost": {...},`
	`      "cost_m2": {...},`
	`      "energy_delivered": {...},`
	`      "energy_delivered_m2": {...},`
	`      "energy_delivered_per_carrier": {...},`
	`      "energy_demand": {...},`
	`      "energy_demand_m2": {...},`
	`      "primary_energy": {...},`
	`      "primary_energy_carrier": {...},`
	`      "primary_energy_carrier_m2": {...},`
	`      "primary_energy_m2": {...},`
	`      "primary_energy_service": {...},`
	`      "primary_energy_service_m2": {...}`
	`    }`
	`  },`
	`  "message": "Asset energy indicators have been calculated",`
	`  "status": "success"`
	`}`

Calculate the operation	`curl --location`
	`'https://smartlivingepc.iti.gr/api/v1/operational_energy_indicators/BUILDING_ID' \`
	`--header 'X-Api-Key: API_KEY'`

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<table>
<tr><td></td><td><pre>{
    "data": {
        "Annual_values": {...},
        "Daily_values": {...},
        "Dates": {...},
        "Energy_classification_boundaries": {...},
        "Energy_consumption_number": 232,
        "Monthly_values": {...}
    },
    "message": "Operational energy indicators have been calculated",
    "status": "success"
}</pre></td></tr>
<tr><td rowspan="2">Calculates the Smart Readiness indicators</td><td><pre>curl --location 'https://smartlivingepc.iti.gr/api/v1/sri/BUILDING_ID' \
--header 'X-Api-Key: API_KEY'</pre></td></tr>
<tr><td><pre>{
    "data": {
        "assessment_results": {
            "aggregated_scores_summary": [...],
            "aggregated_scores_total": [...],
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            "impact_scores": [...],
            "sri_class": "E",
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        },
        "assessor_information": {...},
        "building_information": {...}
    },
    "message": "SRI has been calculated",
    "status": "success"
}</pre></td></tr>
<tr><td rowspan="2">Calculates the Life-Cycle indicators</td><td><pre>curl --location 'https://smartlivingepc.iti.gr/api/v1/lca/BUILDING_ID' \
--header 'X-Api-Key: API_KEY'</pre></td></tr>
<tr><td><pre>{
    "data": {
        "impact_material": [...],
        "impact_structural_group": [...],
        "impacts_stage": [...]
    },
    "message": "LCA indicators have been calculated",
    "status": "success"
}</pre></td></tr>
</table>

The SmartLivingEPC project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069639.

<table>
<tr><td rowspan="2">Calculates the Financial indicators</td><td>

```
curl --location 'https://smartlivingepc.iti.gr/backend/api/v1/financial/BUILDING_ID' \
--header 'X-Api-Key: API_KEY'
```

</td></tr>
<tr><td>

```
{
    "data": {
        "as_designed_costs": {
            "monthly_cost_carrier": [...],
            "monthly_cost_use": [...],
            "total_cost_month": [...],
            "total_cost_month_sqm": [...],
            "total_cost_year": 1306.4159491319901
        },
        "as_operated_costs": {{
            "monthly_cost_carrier": [...],
            "monthly_cost_use": [...],
            "total_cost_month": [...],
            "total_cost_month_sqm": [...],
            "total_cost_year": 11248.8033125
        }},
        "as_predicted_costs": [...]
    },
    "message": "Financial indicatorshave been calculated",
    "status": "success"
}
```

</td></tr>
</table>

In extension to the provided EPC assessment services, external services that are utilized by the SmartLivingEPC platform will also be made available through the aforementioned API in order to be commonly accessible.

The SmartLivingEPC project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069639.

4 Test and Validation

The calculation submodules that reached an advanced development stage and have been documented in the current report have been extensively tested and validated, based on static and dynamic data of pilots #1 (nZEB SmartHouse DIH) and #2 (Frederick's University Main Building).

4.1 Asset-based energy indicators calculation

The energy indicators that are calculated from the JSON-based static building representation of Pilot #2 and are presented in Figure 17-Figure 20. These include the monthly primary and delivered energy for different energy services, as well as, the total primary energy per energy service and energy carrier.

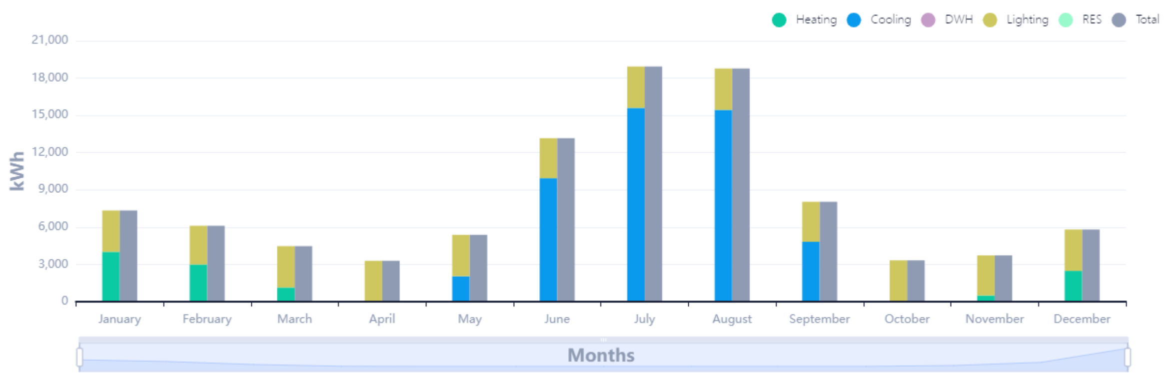

Figure 17. Asset-based energy indicators-monthly primary energy

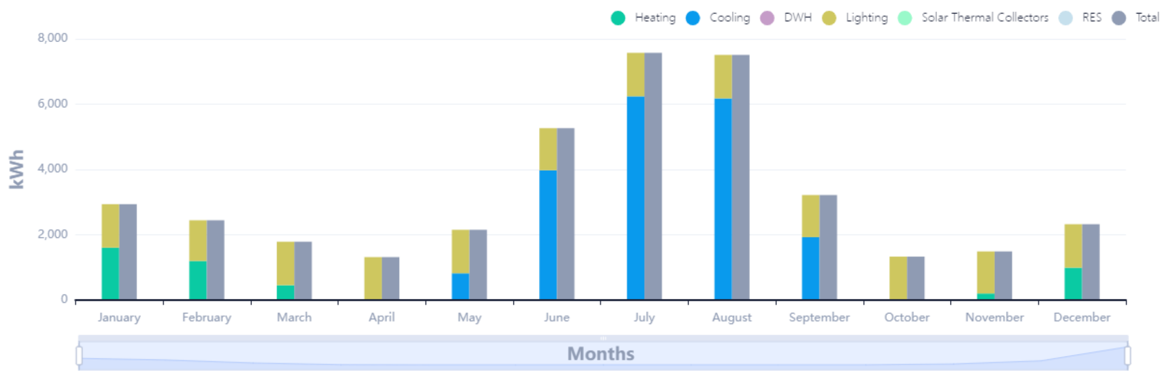

Figure 18. Asset-based energy indicators-monthly delivered energy

The SmartLivingEPC project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069639.

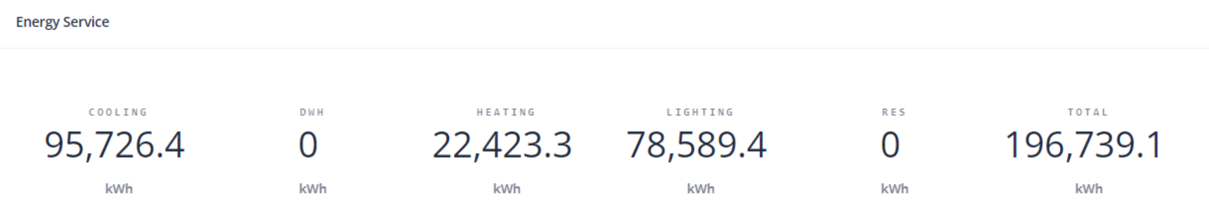

Figure 19. Asset-based energy indicators-total primary energy per energy service

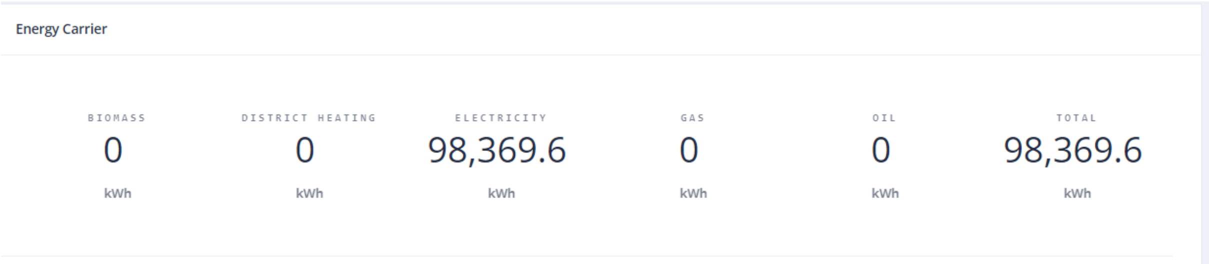

Figure 20. Asset-based energy indicators-total primary energy per energy carrier

4.2 SRI calculation

The SRI calculation results for pilot #1 are visualized in Figure 21-Figure 24. The input information follows the example payload provided in the Annex. The tool then generates the impact and domain overall scores, the detailed scores and the aggregated scores, as well as the total SRI score.

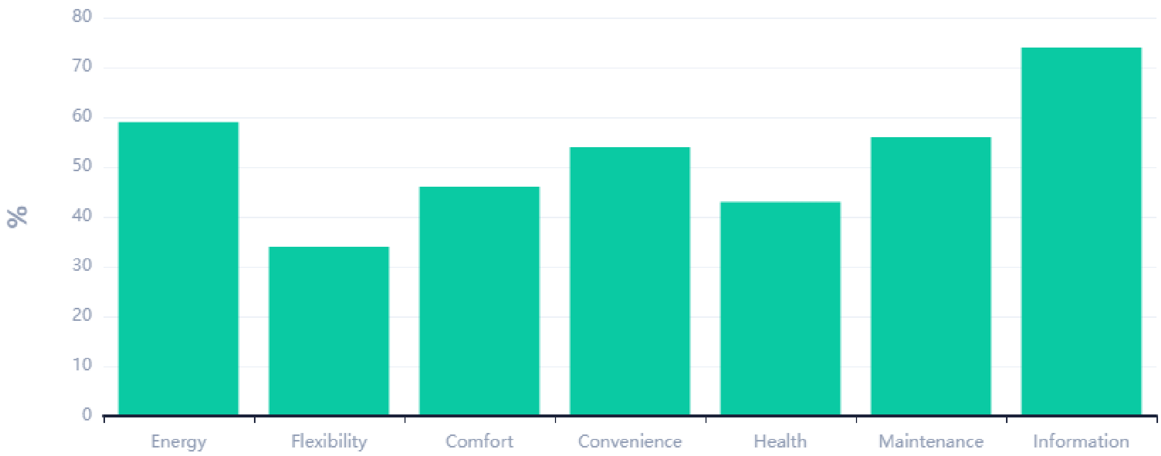

Figure 21. SRI – Impact scores

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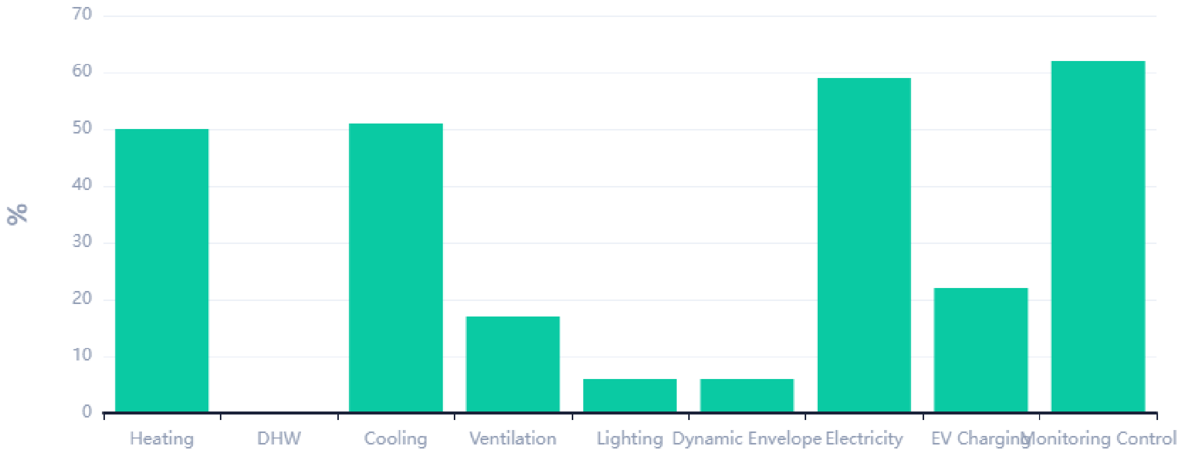

Figure 22. SRI - Domain scores

Domain	Comfort	Convenience	Energy Savings On Site	Flexibility For The Grid And Storage	Health & Wellbeing	Information To Occupants	Maintenance & Fault Prediction
Heating	75	62	80	17	67	67	50
DHW	0	0	0	0	0	0	0
Cooling	75	62	85	17	67	67	50
Ventilation	0	0	0	0	43	67	50
Lighting	20	20	17	0	0	0	0
DynamicEnvelope	20	17	20	0	0	0	0
Electricity	0	60	80	56	0	100	83
EVCharging	0	100	0	25	0	67	0
MonitoringControl	67	59	50	67	50	78	64

Figure 23. SRI - detailed scores

Aggregated Scores

Key functionality 1- building	58
Key functionality 2- user	54
Key functionality 3- grid	34

Domain	Key Functionality 1 - Building	Key Functionality 2 - User	Key Functionality 3 - Grid
Heating	65	68	17
DHW	0	0	0
Cooling	67	68	17
Ventilation	25	27	0
Lighting	8	10	0
DynamicEnvelope	10	9	0
Electricity	82	40	56
EVCharging	0	42	25
MonitoringControl	57	63	67

Figure 24. SRI - aggregated scores

4.3 Operation-based energy indicators calculation

The results of the energy indicators based on the Pilot #1 building operation are displayed in Figure 25 and Figure 26. These include the monthly primary energy for each combination of building services (as

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a result of common metering for more than one service). Additionally, the distribution of the total primary energy per energy service and energy carrier is provided.

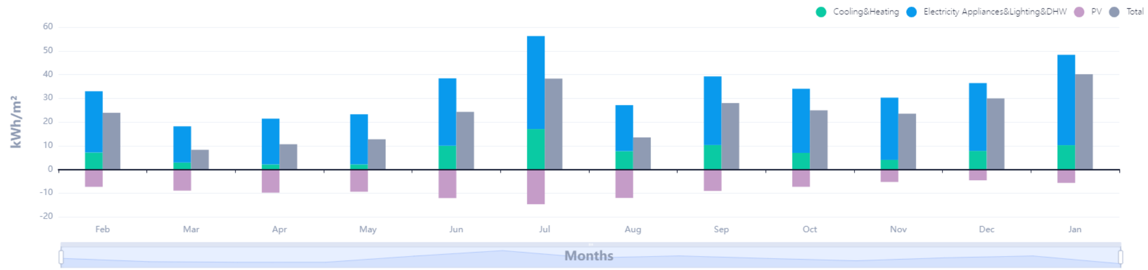

Figure 25. Operation-based energy indicators - monthly primary energy

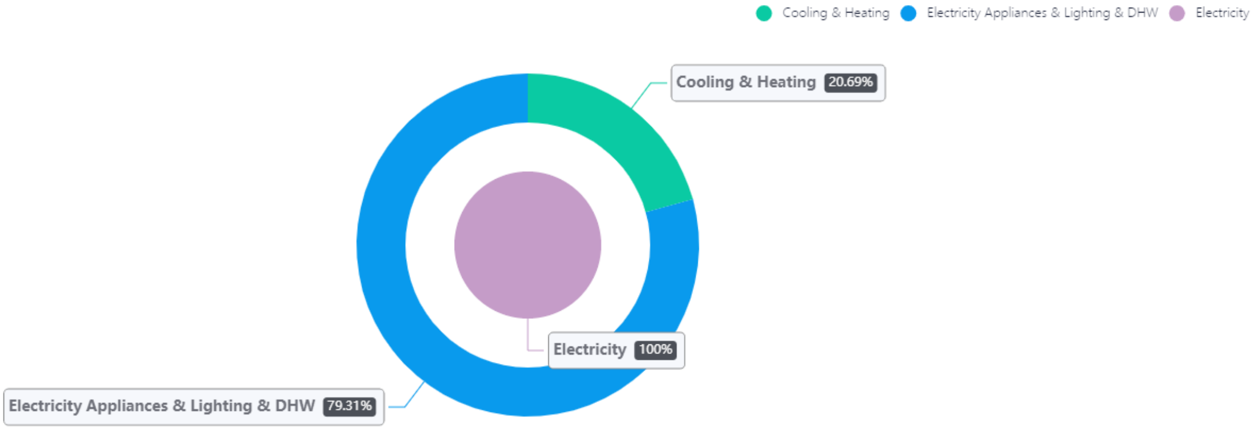

Figure 26. Operation-based energy indicators - annual energy

4.4 Financial indicators calculation

The financial indicators calculation submodule has been tested utilizing the Pilot #2 results from the asset-based and the operation-based energy indicators calculation submodules. An example pricing scheme was considered for determining the as-designed (Figure 27) and the as-operated energy costs (Figure 28). Finally, the as-predicted costs (Figure 29) are calculated based on the total as-operated building cost and selected discount and inflation rate values.

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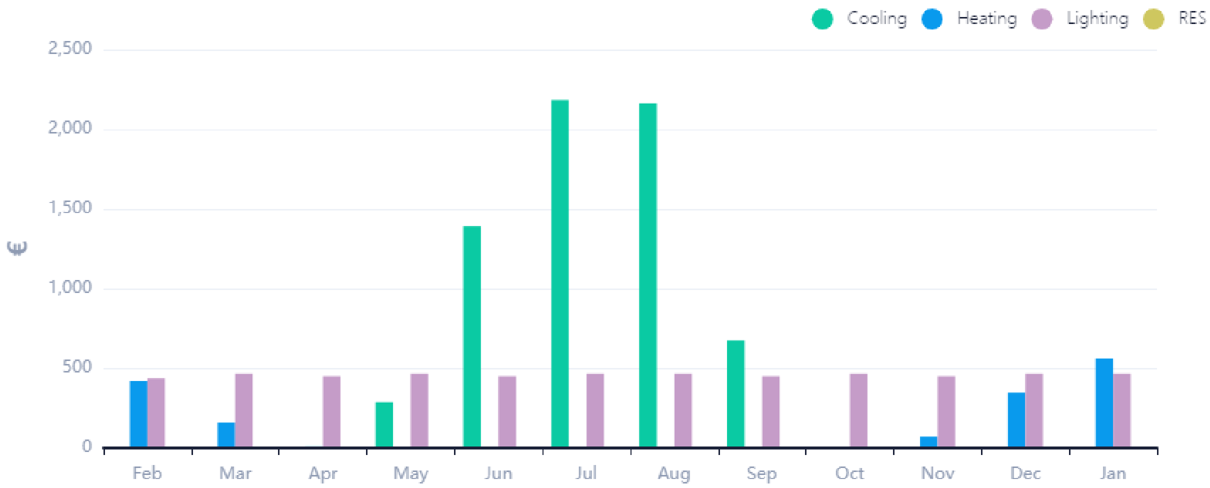

Figure 27. Financial indicators - as-designed costs

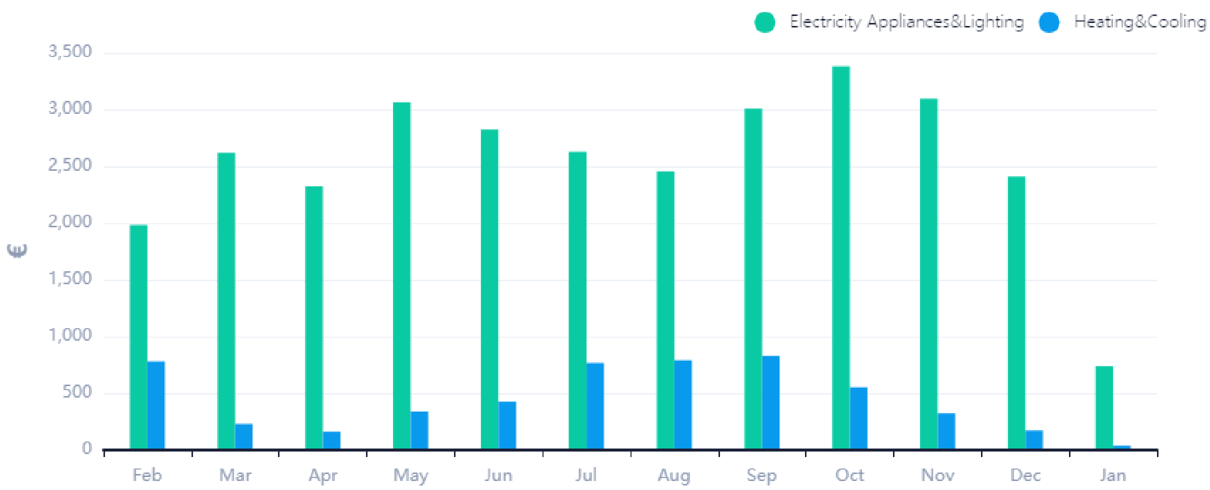

Figure 28. Financial indicators - as-operated costs

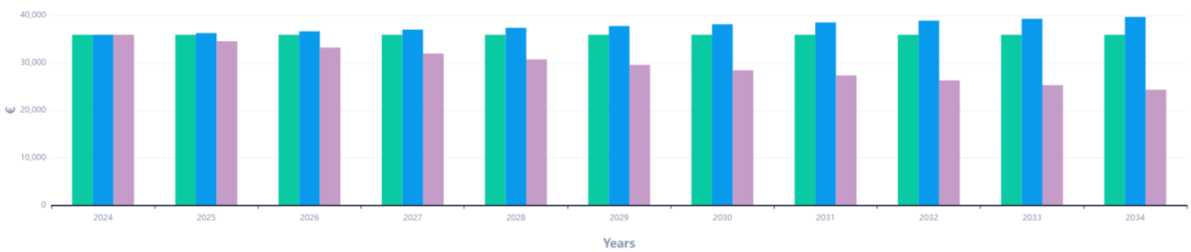

Figure 29. Financial indicators - as-predicted costs

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5 Conclusions

This report summarises the current methodologies overview in SLEPC along with the existing engine developments for the first version of the EPC calculation module and corresponding APIs. Additionally, the most advanced developments have undergone testing and validation, utilizing both static and dynamic data from Pilot #1 (nZEB SmartHouse DIH) and Pilot #2 (Frederick's University Main Building).

The calculation procedure has been partially accomplished and there is ongoing work on executing the computational methods to methodologies, in particular, the energy-based indicators, the SRI score and the financial indicators have achieved significant completion and thus, validated in the pilots. As far as the Operational rating engine, the energy-based indicators also showed considerable progress for progress.

The following list outlines future developments and enhancements for both engines:

- **Methodology Enhancement**: continuous improvement and upgrade of the Asset and Operational ratings based on new data and feedback.
- **Neighborhood-Scale Assessment**: SLEPC extends to developing a methodology for neighborhood-scale assessment which is in progress. This will consider collective impacts on resource consumption and environmental sustainability, incorporating indicators related to building interactions, energy usage, transportation, waste management and green spaces.
- **Indicator Thresholding**: advance with the reference values or benchmarks still undergoing.
- **Score-Class Rating System**: establish a link between the operational score and a related class rating system. This classification enables to cluster buildings into different classes.
- **API Adaptation**: to be adapted to align with the ongoing methodology and the project technologies.
- **Calculation modules**: Actively finalizing the calculation modules, ensuring comprehensive functionality, and will report progress in the next version of this deliverable.

Overall, the EPC calculation module development has already reached an advanced progress state and is anticipated to proceed with the integration of the rest of the methodologies.

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Annex A: EPC calculation data input examples

Asset-based energy indicators


```
{
    "building": {
        "bim_id": "ec89b4ddbdc74e2g9385e06f274cc033",
        "longitude": 22.94309234611111,
        "latitude": 40.63477706888889,
        "name": "nZEB Smart Home DIH",
        "country": "Greece",
        "const_year": 2017.0,
        "use": "Private offices",
        "category": "Tertiary",
        "building_id": "134a31dVLAMsdfUShIBlUJY",
        "location_id": "Thessaloniki",
        "altitude": 0.0,
        "ownership": null
    },
    "systems": [
        {
            "bim_id": "ec89b4ddbvc64e289585e06f274cc033",
            "energy_source": "Electricity",
            "inst_year": null,
            "name": "PV Inclined Modules v8:7 Module:1017274",
            "nom_power": 0.42,
            "orientation": "SW",
            "category": "photovoltaic",
            "building_id": "134a31dVLAMsdfUShIBlUJY",
            "area": 11.124436586039037,
            "tilt": 45,
            "b_system_id": "1F8oBIUbz1LeYG6clvly3U"
        },
                    ...
    ],
    "zones": [
        {
            "bim_id": "ec89b4ddbdc74e2g9385e06f274cc033",
            "name": "Residential:1020802",
            "construction_type": "Heavy",
            "category": "Residential",
            "building_id": "134a31dVLAMsdfUShIBlUJY ",
            "area": 162.40452493231868,
            "volume": 425.75087607810883,
            "zone_usage": "Residential",
            "zone_id": "2XrgBF$IfB8PcTbtAjULre",
            "height": null
        },
                    ...
    ],
    "thermal_systems": [
        {
            "bim_id": "ec89b4ddbdc74e2g9385e06f274cc033",
            "energy_source": "Electricity",
            "system_usage": "heating",
            "n_distribution": 0.92,
            "n_terminal": 0.9,
            "name": "Outdoor  LG simple box KRIPIS v2 SYSTEMS:ARUN100LTE4:924608",
            "n_production": 5.74,
            "category": "heat_pump",
            "efficiency": null,
            "cov_ratio": 0.5,
            "zone_id": "2XrgBF$IfB8PcTbtAjULke",
            "capacity": 31500.0,
            "z_system_id": "2THiBz3wjvCOnl2d81HHGD"
        },
                    ...
    ],
    "spaces": [
        {
            "bim_id": "ec89b4ddbdcq4e289585e06f274cc033",
            "space_usage": "engine_room_36",
            "name": "36",
            "category": "space",
            "area": 8.82857527968473,
            "space_id": "1F8oBIUbz1LwYv6clvlyFq",
            "volume": 22.954295727180295,
            "zone_id": "0L6Ksk7iTBT9hmk0knrbY3",
            "lighting": 0.0,
            "height": 2.9999999999999996
        },
                    ...
```

```
    ],
    "elements": [
        {
            "bim_id": "ec89b4ddbdc74e2g9385e06f274cc033",
            "u_value": 0.3,
            "name": "Basic Wall:Generic - 300mm:1017293",
            "element_id": "1F8oBIUbz1LwYG6cldly2f",
            "orientation": "W",
            "category": "Opaque element",
            "contact": "External Air",
            "area": 12.78384390797772,
            "f_shade": 1.0,
            "space_id": "1F8oBIUbz1LwYG6cevlyF$",
            "tilt": 90,
            "style": "External Wall",
            "element_usage": "opaque_contact_ext_air",
            "absorption": 0.7
        },
                    ...

    ],
    "thermal_bridges": [
        {
            "bim_id": "ec89b4ddbdc74e2g9385e06f274cc033",
            "name": null,
            "space_id": "1F8oBIUbz1LwYG6clvcyFF",
            "length": 0.0,
            "linear_thermal_trasmitance": 11.123485766438185,
            "bridge_id": "2XrgBF$IfB8PcTbtAjULkf_1F8o2IUbz1LwYG6clvlyFF"
        },
                    ...

    ],
    "sensors": [
        {
            "bim_id": "ec89b4ddbdc7ve2g9385e06f274cc033",
            "sensor_id": "2w48yaP$r6tRw2QCjYS_GO",
            "measurement_types": [
                "MOVEMENTSENSOR",
                "TEMPERATURESENSOR",
                "LIGHTSENSOR"
            ],
            "device_id": "0916e774-f7cc-4c4a-b326-0cs5er782a24",
            "name": "CO2 Sensor:SH_C02_Temp:1026738",
            "space_id": "1F8oBIUbz1LwYG6clvlyFY"
        },
                    ...
    ],
    "meters": [
        {
            "bim_id": "ec89b4ddbdc74e2g9385e06f274cc033",
            "measurement_types": [
                "ENERGYMETER",
                "POWERMETER"
            ],
            "device_id": "1da7c2e1-2797-5d10-b5fa-bbbaf5402927",
            "name": "Energy_Meter:Energy_PCC:1023878",
            "refers_to": [...],
            "energy_service": [
                "Electricity Appliances",
                "Lighting",
                "DHW"
            ],
            "space_id": "1F8oBIUbz1LwYG6cfvlyFq",
            "energy_carrier": "Electricity",
            "meter_id": "2w48yaP$r6tRwzQCjYSz4i",
            "connected_with": null
        },
                    ...
    ]
}
```

SRI


```
{
    "assessor": {
        "name": "CERTH",
        "organization": "SmartLivingEPC",
        "email": "test@iti.gr"
    },
    "building_info": {
        "building_id": "test",
        "building_type": "Residential",
        "building_usage": "Other",
        "construction_year": 2017,
        "location": "Greece",
        "useful_area": 301,
        "state": "Original",
        "description": "",
        "address": ""
    },
    "smart_services": [{
                "domain": "Heating",
                "presence": 1,
                "services": [{
                        "service": "H-1b",
                        "applicable": true,
                        "levels": [3, 90, 0]
                    },
                    ...
                 },
                 {
                "domain": "Cooling",
                "presence": 1,
                "services": [{
                        "service": "C-1b",
                        "applicable": true,
                        "levels": [3]
                    },...
                 },
                 {
                "domain": "DHW",
                "presence": 1,
                "services": [...]
                 },...
    ]
}
```


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Operation-based energy indicators


```
[
    {
        "device_id": "47606a0d-5300-4b02-a3ea-d01cc4fbff29",
        "value": 1.2,
        "meas_type": "ENERGYMETER",
        "timestamp": "2022-01-01T00:00:00",
        "unit": "kWh"
    },
    {
        "meas_type": "ENERGYMETER",
        "value": 26.95814361,
        "unit": "kWh",
        "timestamp": "2022-01-11T00:00:00",
        "device_id": "264042a5-6479-4f9b-8360-4dc069c7784e"
    },
    …
]
```


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Financial indicators –energy prices


```
{
  "carrier_prices": [
    {
      "carrier": "Electricity" ,
      "month": "January" ,
      "price": 0.2
    } ,
    {
      "carrier": "Electricity" ,
      "month": "February" ,
      "price": 0.2
    } ,
    {
      "carrier": "Electricity" ,
      "month": "March" ,
      "price": 0.2
    } ,
    {
      "carrier": "Electricity" ,
      "month": "April" ,
      "price": 0.2
    } ,
    {
      "carrier": "Electricity" ,
      "month": "May" ,
      "price": 0.2
    } ,
    {
      "carrier": "Electricity" ,
      "month": "June" ,
      "price": 0.2
    } ,
    {
      "carrier": "Electricity" ,
      "month": "July" ,
      "price": 0.2
    } ,
    {
      "carrier": "Electricity" ,
      "month": "August" ,
      "price": 0.2
    } ,
    {
      "carrier": "Electricity" ,
      "month": "September" ,
      "price": 0.2
    } ,
    {
      "carrier": "Electricity" ,
      "month": "October" ,
      "price": 0.2
    } ,
    {
      "carrier": "Electricity" ,
      "month": "November" ,
      "price": 0.2
    } ,
    {
      "carrier": "Electricity" ,
      "month": "December" ,
      "price": 0.2
    }
  ]
}
```

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

https://www.smartlivingepc.eu/en/

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

https://twitter.com/SmartLivingEPC

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

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