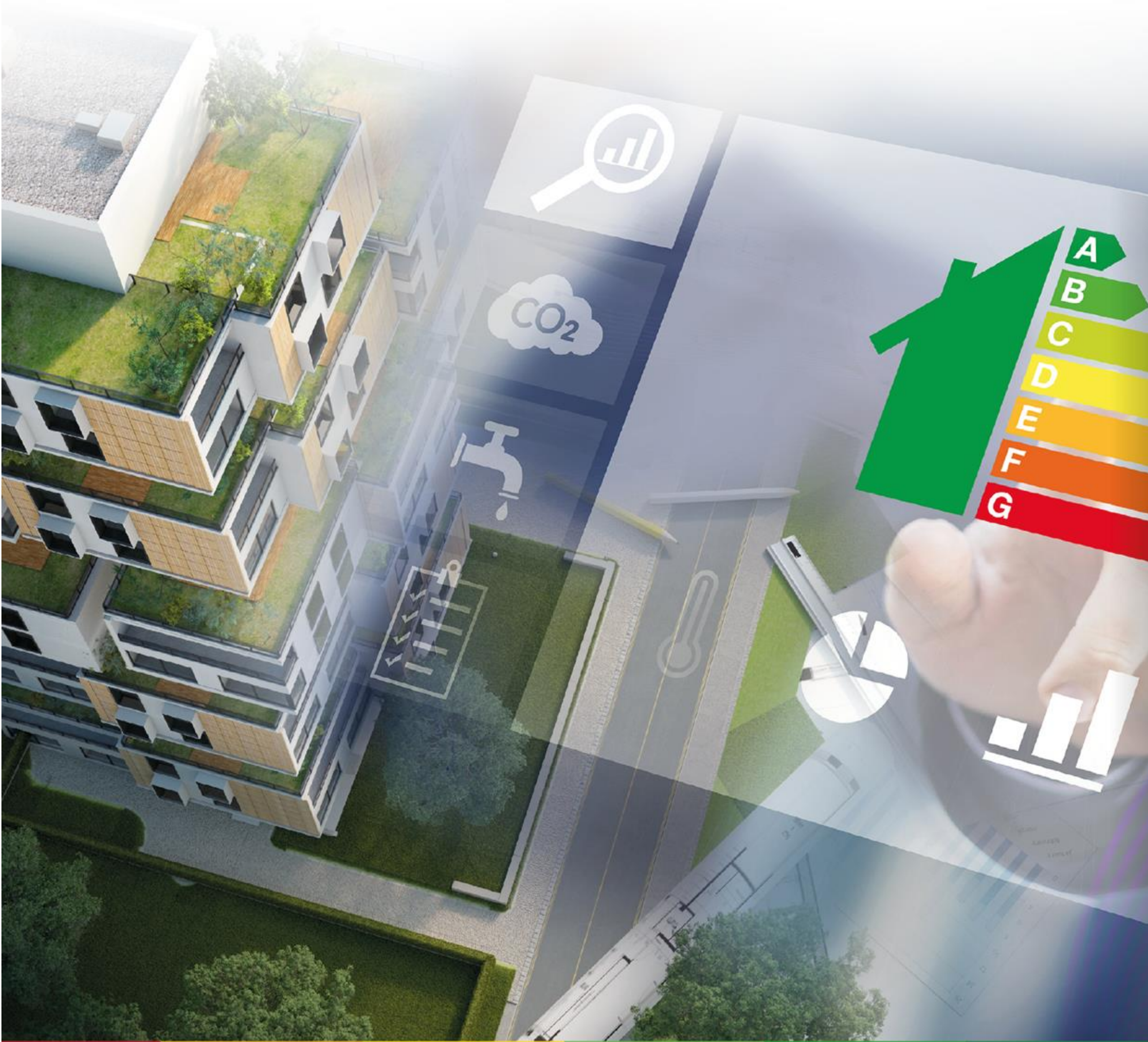
SmartLivingEPC Manual for implementation v2



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SmartLivingEPC Manual for implementation v2

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Executive Summary

This document describes the **theoretical background, methodology and calculation steps of the SmartLivingEPC scheme**. It is the synthesis resulting from the analysis and unification of the methodological description of each component of the SmartLivingEPC scheme, developed within WP2 and WP3 of the project.

It also includes the **user manual on the SmartLivingEPC Web Platform**, which constitutes the practical implementation of the SmartLivingEPC scheme in digital tools developed in WP4 and WP5. In addition, it outlines the strategy for **training sessions and workshops**, aiming to gather feedback from target stakeholders, concerning potential improvements of the scheme fostering the implementation of the designed methodology for enhanced building performance assessments.

It is addressed to independent experts eligible to issue energy performance certificates of buildings (i.e., EPB assessors) with a view to facilitate bottom-up implementation of the SmartLivingEPC scheme.

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

The following acronyms and abbreviations are used throughout the text. The list of terms and respective description is shown below in alphabetical order.

Term	Description
BAC	**Building automation and control**. Products, software, and engineering services for automatic controls, monitoring and optimisation, human intervention, and management to achieve energy-efficient, economical, and safe operation of building services equipment. [Source: ISO 52120-1:2021(en), 3.9] "Control" does not imply that the system or device is restricted to input/output, processing, optimisation, management, and operator functions. Processing of data and information is possible. Mainly field and control devices, switchgear assembly, cabling, communication and computing devices, system software and functions achieved by engineering services.
BACS	**Building automation and control system**. System, comprising all products, software and engineering services for automatic controls (including interlocks), monitoring, optimization, for operation, human intervention, and management to achieve energy-efficient, economical, and safe operation of building services. Source: ISO 52120-1:2021(en), 3.3 Note 1 to entry: BACS is also referred to as BMS (building management system). Note 2 to entry: The use of the word 'control' does not imply that the system or device is restricted to control functions (3.5). Processing of data and information is possible. Note 3 to entry: If a building control system, building management (3.4) system, or building energy management system complies with the requirements of the ISO 16484 series, it should be designated as a building automation and control system (BACS). Note 4 to entry: Building services are divided in technical, infrastructural and financial building services and energy management is part of technical building management (3.13). Note 5 to entry: Building energy management system is part of a BMS. Note 6 to entry: The building energy management system comprises data collection, logging, alarming, reporting, and analysis of energy usage, etc. The system is designed to reduce the energy consumption, improve the utilization, increase the reliability, and predict the performance of the technical building systems (3.14), as well as optimize energy usage and reducing its cost. [SOURCE: ISO 16484-2:2004, 3.31, modified — Notes to entry 1, 4, 5 and 6 have been added.]
BEMS	**Building energy management system**. Comprises data collection, logging, alarming, reporting, and analysis of energy usage, etc. The system is designed to reduce the energy consumption, improve the utilisation, increase reliability, and predict performance of the technical building systems, as well as optimise energy usage and reducing its cost.

BM	**Building management**. Totality of services involved in the management operation and monitoring of buildings (including plants and installations). Note 1 to entry: Building management can be assigned as part of facility management. [Source: ISO 52120-1:2021(en), 3.4]
Building fabric	**Building fabric**. All physical elements of a building, excluding technical building systems EXAMPLE: Roofs, walls, floors, doors, gates and internal partitions. [Source: ISO 52000-1:2017(en), 3.1.5] Note 1 to entry: It includes elements both inside and outside of the thermal envelope, including the thermal envelope itself. Note 2 to entry: The fabric determines the thermal transmission, the thermal envelope airtightness and (nearly all of) the thermal mass of the building (apart from the thermal mass of furniture and technical building systems). The fabric also makes the building wind and water tight. The building fabric is sometimes described as the building as such, i.e., the building without any technical building system
Building service	**Building service**. Service provided by technical building systems and by appliances to provide acceptable indoor environment conditions, domestic hot water, illumination levels and other services related to the use of the building. The services included in EPB assessments are referred to as “EPB services”. Contrarily those not included as “non-EPB services”.
Distant	*Related to the relative location and interaction of the energy source and the building.* **Distant**. Not on-site nor nearby.
EPB	**Energy Performance of Buildings**
EPC	**Energy Performance Certificate**
EPD	**Environmental Product Declaration**
EV	**Electric Vehicle**
Functionality level	As a term within the SRI calculation methodology, means the level of smart readiness of a smart-ready service.
HVAC	**Heating Ventilation and Air-Conditioning**
IEQ	**Indoor Environmental Quality**
LCA	**Life Cycle Assessment**
LCC	**Life Cycle Costing**
Nearby	*Related to the relative location and interaction of the energy source and the building.*

	Nearby. On local or district level.
On-site	*Related to the relative location and interaction of the energy source and the building.* **On-site**. Premises and the parcel of land on which the building(s) is located and the building itself. On-site is defining a strong link between the energy source (localisation and interaction) and the building.
Reference size	Relevant metric to normalise the overall or partial output of any component assessment to the size of the assessed object and for comparison against benchmarks
SRI	**Smart Readiness Indicator**
Smart-ready service	As a term within the SRI calculation methodology, means a function or an aggregation of functions provided by one or more technical components or systems. A smart-ready service makes use of smart-ready technologies and orchestrates them into higher-level functions.
Smart-ready technology	As a term within the SRI calculation methodology, means a technological enabler for one or more smart-ready services.
TBS	**Technical building systems**. Technical equipment for heating, cooling, ventilation, humidification, dehumidification, domestic hot water, lighting, and electricity production. A technical building system is composed of different subsystems.
Technical domain	As a term within the SRI calculation methodology, means a collection of smart-ready services which, together, realise an integrated and consistent part of the services expected from the building or building unit.
UAT	**User Acceptance Test**.

The terms and definitions outlined above reflect those used in standardisation. ISO and IEC maintain terminological databases at the following addresses.

- ISO online browsing platform: available at https://www.iso.org/obp

-IEC Electropedia: available at https://www.electropedia.org/

In absence of definition or doubt regarding the meaning of a term, the above sources should be used as default.

1 Introduction

SmartLivingEPC rating methodology comprises two types of assessment, asset – based on calculations, and operational – based on measurements. Also, while being focused on energy performance, it includes complementary aspects such as smartness, indoor environmental quality, sustainability. In addition, it can be applied to buildings or building units, as well as to complexes. The assessment types assessed objects and dimensions covered by the SmartLivingEPC framework are outlined in Table 1.

Table 1. SmartLivingEPC scheme. Overview of assessment types

Assessment type	Assessed object	Dimension	
Asset	Building or building unit	Energy performance	
		Smart Readiness	
		Indoor Environmental Quality (IEQ)	Visual comfort
			Acoustic comfort
			Thermal comfort
			Indoor Air Quality
		Sustainability	
	Complex	Environmental	Neighbourhood Services
			Renewable Energies
			Demand Side Management
		Infrastructure	EV chargers
			Mobility and Transport
			Neighbourhood building inventory
		Social	Energy Poverty
			Quality of Life
Operational	Building or building unit	Energy performance	
		Indoor Environmental Quality (IEQ)	Thermal Comfort
			IAQ
			Occupant feedback
			Virus Risk
		Finances	
	Complex	Environmental	Neighbourhood services
			Renewable Energies
		Operational	Neighbourhood´s Building Functioning

The assessment methodology is envisioned to integrate the findings of regular building technical system audits, and is fully compatible with digital building models, digital twins, and digital building logbooks.

1.1 Scope and objectives of the deliverable

This document covers both theoretical background of the SmartLivingEPC scheme and its practical implementation in the SmartLivingEPC Web Platform.

The objective is to transparently describe the SmartLivingEPC scheme, detailing in a structured manner for each component the output data, input data, and calculation procedure. Second, to guide prospective users of the SmartLivingEPC Web Platform on its use, describing the tool components and presenting use cases. In addition, it includes the strategy to be followed for the validation of the SmartLivingEPC Framework through a set of workshops.

Although it is a technical document mainly addressed to building performance assessors (i.e., architects and engineers currently practicing on any of the dimensions covered by the SmartLivingEPC scheme), it may be useful to other stakeholders in the value chain, such as regulators dealing with EPBD implementation vis-à-vis building assessments and certification schemes. Further target groups are parties wanting to motivate their assumptions by classifying the building energy performance for a dedicated building stock. However, a minimum technical background is required to fully grasp the details of the document.

1.2 Structure of the deliverable

This document is structured as follows. In section 2, the theoretical background of the SmartLivingEPC scheme is outlined, with dedicated sub-sections. Section 2.1 and section 2.2 describe a general introduction and the overarching framework and procedures applicable for the SmartLivingEPC scheme. Then, in section 0 the asset assessment at the building level is described; in section 2.4, the operational assessment at the building level with a subsection focused on each of the components indicated in Table 1. In section 2.5, the asset assessment at the complex level assessments is described in detail, while the operational assessment is in section 0. In section 3, the user manual of SmartLivingEPC Web Platform is included, with dedicated sub-sections. In section 4 the strategy for the validation of SmartLivingEPC Framework through workshops is described. Section 5 includes the conclusions and 6 the bibliographic references. Annexes are included in the end to ease the reading of the document.

1.3 Relation to Other Tasks and Deliverables

Task 6.1 deals with the compilation of the methodological aspects of the SmartLivingEPC scheme. Consequently, it is strongly related to WP2 and WP3, in which the asset and operational methodological frameworks are laid out, respectively. More specifically, Task 6.1 requires input from virtually all tasks within WP2 and WP3 as indicated in Figure 1.

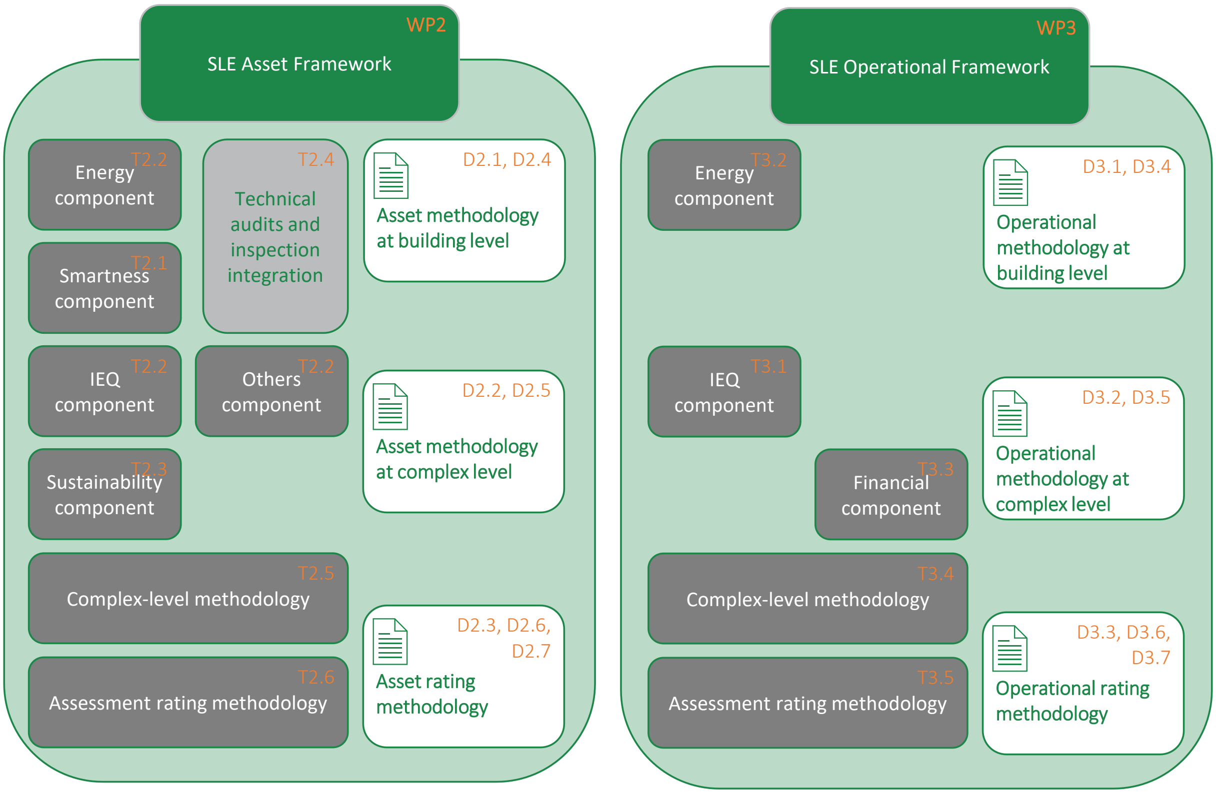


Figure 1. Tasks and deliverables related to Task 6.1. SmartLivingEPC assessment methodology

Task 6.1 deals with the user manual of the SmartLivingEPC Web Platform, which integrates the services developed within the project, in the framework of Task 5.4. Thus, Task 6.1 is not only related to WP2 and WP3, but also indirectly SmartLivingEPC digital services (e.g., Common Information Exchange Model, Digital Twin, added-value AI tools), developed in WP4 and WP5 activities.

Lastly, Task 6.1 includes the preparation of the workshops aiming to gather feedback from stakeholders concerning potential improvements of the tool a. To that end, coordination with tasks related to validating the project results is needed, as illustrated in Figure 2.

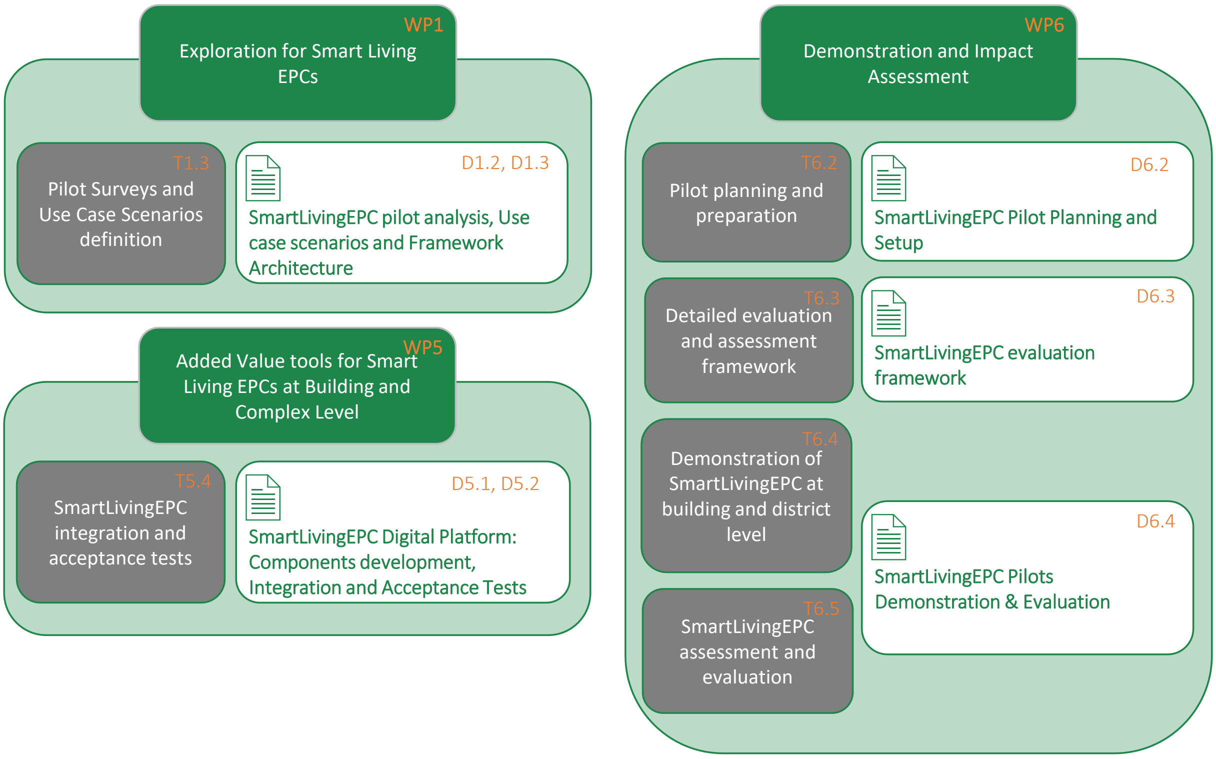


Figure 2. Tasks and deliverables related to Task 6.1. SmartLivingEPC demonstration

The use cases defined in D1.3 define the interaction of the different users with the SmartLivingEPC Framework and its components. They are the base for the fundamental functional requirements of SmartLivingEPC Web Platform, which are described in D5.1. The functional requirements detail the platform's operational characteristics, the involved components, the primary rationale behind their design, and the criteria used for their evaluation. As a result of Task 5.4 activities, user acceptance tests (UATs) for the SmartLivingEPC Web Platform are defined aiming to simulate real-world use and ensure that the platform meets user expectations.

In addition, the rest of tasks within WP6 are significantly related to Task 6.1, notably Task 6.4 and Task 6.5. These tasks will implement the project methodologies and integrated solution in real-life buildings and evaluate stakeholders' acceptance. The validation workshop strategy defined in this document will be rolled out in the framework of those tasks, hence the results will be reported in D6.4 at the end of the project.

The needed input has been retrieved from the related deliverables. Also, by having bilateral exchanges with the involved partners as needed. In the Consortium Meeting #5 a working group with all the methodology developers was held to clarify joint open aspects.

2 SmartLivingEPC Scheme. Theoretical background

2.1 Introduction

This section deals with the description of the methodology for the SmartLivingEPC scheme. The subsequent sections deal with the theoretical framework behind the asset and operational assessment, both at the building and complex level. As indicated in Table 1, the SmartLivingEPC scheme considers two types of assessed objects (i.e., building and complex), two types of assessments (i.e., asset and operational), which are composed by several dimensions.

Table 2. SLE assessment types at the building level

Type	Component	Input data		
		Use	Climate	Building
Calculated (asset) – at the building level	Energy performance	Standard	Standard	Design, Actual
	Smart Readiness	Standard	Standard	Actual
	IEQ	Actual	Actual	Actual
	Sustainability	Standard	Standard	Actual
Measured (operational) – at the building level	Energy performance	Standard	Standard	Actual
	IEQ	Actual	Actual	Actual
	Finances	Standard	Standard	Actual

Regardless of the object and assessment type, the most important dimension is energy performance, while the remaining complement it. Thus, the theoretical methodology for the SmartLivingEPC scheme is structured based on the whole set of EPB standards, which constitute the standard series aimed at the international harmonisation of the methodology for assessing the energy performance of buildings. In ISO/TR 52000-2 [1] a table can be found describing the modular structure of the EPB standards, with references to the relevant standards and accompanying technical reports. A summarised reproduction is depicted in Table 3.

The overarching modular structure of the EPB standards has the following four main areas.

- M1. Overarching standards.
- M2. Building as such.
- M3-M11. Technical Building Systems under EPB (M3-Heating, M4-Cooling, M5-Ventilation, M6-Humidification, M7-Dehumidification, M8-Domestic Hot Water, M9-Lighting, M10-Building Automation and Control, M11-Electriciy production).
- M12-M13. Other systems or appliances (non-EPB).

Table 3. EPB Standards modules and submodules. Reproduced from [2].

Main area	Overarching	Building as such	Technical Building Systems
Module	**M1**	**M2**	**M3-M11**
Submodule	**Description**		
1	General	General	General
2	Common terms and definitions; symbols; units and subscripts	Building Energy Needs	Needs
3	Applications	(Free) Indoor conditions without systems	Maximum load and power
4	Ways to Express Energy Performance	Ways to Express Energy Performance	Ways to Express Energy Performance

5	Building Functions and Building Boundaries	Heat Transfer by Transmission	Emission & control
6	Building Occupancy and Operating Conditions	Heat Transfer by Infiltration and Ventilation	Distribution & control
7	Aggregation of Energy Services and Energy Carriers	Internal Heat Gains	Storage & control
8	Building Zoning	Solar Heat Gains	Generation & control
9	Calculated Energy Performance	Building Dynamics (thermal mass)	Load dispatching and operating conditions
10	Measured Energy Performance		
11	Inspection		
12	Ways to Express Indoor Comfort		BMS
13	External Environment Conditions		
14	Economic Calculation		

Nevertheless, referring to the EPB standards does not imply that all the decisions regarding methods and required input data to perform the assessments are unequivocally defined. As indicated in [3], all EPB standards provide certain flexibility by introducing a normative template in Annex A for regulators in each context to specify the national or regional choices. An Annex B is also provided with informative default choices. Furthermore, as indicated by the U-CERT project[1], the EPB standards provide additional flexibility by defining more than one pathway for the assessment in the body of text which requires making decisions out of the scope of the Annex A/B.

Topics addressed in this document can be subject to public regulation. Consequently, public regulation on the same topics can even, for certain applications, make use of this document. Legal requirements and choices are in general not published in standards but in legal documents. To avoid double publications and difficult updating of double documents, a national annex may refer to the legal texts where national choices have been made by public authorities. Different national annexes or national data sheets are possible, for different applications.

2.2 Overarching framework and procedures

2.2.1 Output of the method

The SmartLivingEPC assessments provide many intermediate and final quantitative results, the SmartLivingEPC indicators. The main output, regardless of the assessment type, is an indicator of the overall performance of the assessed object across diverse dimensions, as well as overall performance indicators per component. In addition, partial indicators can be defined for sub-aspects of the assessed object, such as at the level of any of its technical (sub)systems, to the fabric, to individual elements for the building-level assessment. Analogously for complex-level assessments.

The SmartLivingEPC indicators are listed in each section. At the building level, in Table 7 for the asset assessment and in Table 30 for the operational assessment; at complex level, in Table 55 for the asset assessment and in Table 72 for the operational assessment. Furthermore, the SmartLivingEPC indicators, when normalized to the assessed object reference size, can be established into ratings, which are also described in each section.

[1] More information: https://cordis.europa.eu/project/id/839937/results

2.2.2 Overarching preparation steps

In preparation of the SmartLivingEPC assessment, regardless of the number of components to be assessed, the parameters outlined in Table 6 must be identified. They shall be linked to a unique identifier for each specific case. Such identifier shall be used throughout the whole SmartLivingEPC assessment.

Object type

EN ISO 52000-1:2017 defines in its clause 6.2.1 the object to be assessed as a building, part of a building or portfolio of buildings, located on a single building site. SmartLivingEPC aligns with such standard with the "building level" but expands the type of assessed object by including the "complex level".

Application type

EN ISO 52000-1:2017 states in its clause 6.2.3 that the type of application shall be identified. The possible applications include checking compliance with energy performance requirements, energy performance certification and energy performance inspection. The SmartLivingEPC scheme is mainly bound for a certification-type of application, although the assessments therein may be leveraged for others.

Assessment type

EN ISO 52000-1:2017 defines in its clause 6.2.4 the type of assessment as calculated (asset) and measured (operational), with diverse subtypes depending on the input data used and the type of application. The SmartLivingEPC scheme includes calculated and measured assessments.

Building (and/or space) category

EN ISO 52000-1:2017 indicates in its clause 6.2.2 that the different categories of the assessed object with respect to the main use shall be identified, because of the possible impact on the next steps in the procedures. Normally, the allocation of a building category has legal implications. For example, related to specific building regulations. The EPB standards enable differentiating space categories within a building. Hence, each space category shall be defined. Otherwise, each space category is equated to the building category.

Each space category is characterised by a set of conditions for use for the energy performance assessment (calculated or measured), as specified in the standards covering EPB module M1-6.

The building (and/or space) categories supported by the SmartLivingEPC scheme are those outlined in Table B.5 in EN ISO 52000-1:2017 [3].

Building useful floor area and air volume

Following EN ISO 52000-1:2017clause 9.3, for each space (index space, *i*) the useful area, $A_{use;space,i}$, is assessed. This is needed to quantify specific conditions for use that are expressed per m^2 of useful floor area (e.g., occupancy) and for the application of the simplifications and the zoning and (re-) allocation rules. The useful floor area shall be specified in such a way that the sum of the useful floor area of individual spaces is the same as the useful floor area of the thermal zone or service area of these spaces. In addition, for each space the air volume, $V_{air;space,i}$, is assessed. This is needed as basis for the air volume per thermal zone, in input for the thermal calculations in relation to ventilation and moisture.

The choice with respect to the type of dimensions to determine the useful floor area made by the SmartLivingEPC scheme is the net area.

Building services

Following EN ISO 52000-1:2017 clause 6.2.5, the type of combination of services that shall be considered in the SmartLivingEPC assessment shall be identified. This is particularly relevant for the energy performance dimension but also has an influence on others such as the smartness component because of the overlaps between services and technical building domains. These parameters may be directly or indirectly related to national or regional regulations.

The building services supported by the SmartLivingEPC scheme are depicted in Table 4:

Table 4. Building services considered in the energy performance assessments. Building level.

Combination of services type	Asset assessment		Operational assessment	
Building service	Residential	Non-residential	Residential	Non-residential
Heating	Yes	Yes	Yes	Yes
Cooling	Yes	Yes	Yes	Yes
Ventilation	Yes	Yes	Yes	Yes
Humidification	Yes	Yes	Yes	Yes
Dehumidification	Yes	Yes	Yes	Yes
Domestic hot water	Yes	Yes	Yes	Yes
Lighting	Yes	Yes	Yes	Yes
External lighting	No	No	No	No
People transport (e.g., elevators, escalators, etc.)	No	No	No	No
Other services consuming electricity (e.g., appliances)	No	No	No	No

Consideration shall be given for buildings that are not equipped with all services for which the energy performance shall be assessed. Possible options are:

- "Assumed system": if the type of space is supposed to be thermally conditioned, then the space is considered as thermally conditioned, disregarding the absence of actual heating or cooling provision, so assuming a fictitious system or the same system as in the adjacent spaces.
- "Presence of system": If a heating or cooling sub-system is present, then the space is considered as thermally conditioned, disregarding the supposed use.

The choice has implications for the calculation, depending on the principle:

- "Assumed system": provide specification of a default technical system for each missing service. Sometimes called "fictitious service". This is a way to avoid violation of a level playing field, in case of under-installation or absence of installation. In these cases, simply not taking the heating or cooling into account would lead to a better energy performance than when the installation is present. Unless compensated by an indication of the lower comfort.
- "Presence of system": Do not take into account energy use for a specific service if there is no technical building system present for that service. As a consequence, a possible better energy performance for building missing some services. A possibility is to compensate this by highlighting the discomfort with a complementary discomfort indicator.
- "Other principle" is also allowed by the EPB standards, which shall be described.

On this note SmartLivingEPC scheme opts for the "presence of system" principle.

In addition, certain thermally unconditioned spaces may, for reasons of simplicity, be assumed to have the same conditions of use as the adjacent thermally conditioned spaces and then joined. This might be the case of attics, staircases, atriums and garages. The choice whether these enclosed spaces are assumed to have the same conditions of use as the adjacent thermally conditioned spaces may have a very strong impact on the calculated, but also for measured energy performance. Moreover, it may be relevant to know if the energy used in these kinds of spaces has to be included in the measured energy performance.

Complex area

At urban scale, the methodology defines "Complex Building" as a closed polygon, jointly determined by the payer and the technical evaluator. This polygon delimits the urban area under assessment. It is carefully constructed to ensure that it is free of internal gaps or overlaps. The boundaries of this polygon will be demarcated by significant elements that may include infrastructure, geographic features, political or administrative divisions, among others. These significant elements comprise a wide range of factors. These may include common service infrastructure such as transportation networks or utility systems, community renewable energy facilities, natural elements such as rivers, mountains and forests, political or administrative boundaries such as postal codes or energy communities, among others. The terms: neighbourhood, evaluation area, assessment area, polygonal area, delimited area, complex building, are used synonymously to refer to "Complex Area".

Reference size and normalisation

Following EN ISO 52000-1:2017 clause 9.4.1, overall and partial performance can be normalised to the building size, by relating it to one or more of the relevant metrics for the building size, such as reference volume or reference floor area.

Assessing the size of a building or part of a building implies the choice which spaces are considered to be included. This choice is related to the space category. For specific space categories a fraction (between 0 and 1) of the size may be appropriate. These kind of choices regarding the size of which spaces are included in the size of the building may have a very strong impact on the numerical indicator for the energy performance.

The choice of reference size for the SmartLivingEPC scheme is Table 5:

Table 5. Building services considered in the energy performance assessments. Building level.

Quantity	Asset assessment		Operational assessment	
	Unit	Specification and/or reference to document with more information	Unit	Specification and/or reference to document with more information
Reference floor area	m^2	Useful floor area as in Table B.20 of this document, with fractions according to Table B.22 EN ISO 52000-1:2017	Yes	Useful floor area as in Table B.20 of this document, with fractions according to Table B.22 EN ISO 52000-1:2017

This leads to **Equation 1** for normalisation of a quantity X by the reference size S, with Y being the normalised quantity.

$$Y = \frac{X}{S} \qquad \text{Equation 1}$$

Assessment boundary and perimeters

The assessment boundary is related to the assessed object.

Energy performance for a part of the assessed object and/or per service is calculated according to normative Annex E in [3].

Energy can be imported or exported through the assessment boundary. The assessment boundary defines where the actual value of the delivered or exported energy is calculated or measured.

Some of these energy flows can be quantified based on the meters (e.g., gas, electricity, district heating). For active solar, wind or water energy systems the assessment boundary is the output of the solar panels, solar collectors or electric generation devices.

The delivered energies are classified according to the following parameters (origin or destination): on-site, nearby, and distant.

Energy weighting factors (e.g., primary energy, CO_2) are defined for each energy flow delivered or exported through the assessment boundary, considering the origin for delivered and the destination for exported energy.

In case of energy produced on-site or nearby, the weighting factors are calculated according to the relevant EPB standards. Inclusion or exclusion of energy contribution to the perimeter (origin) depends on the calculation objective (e.g., defining the renewable energy ratio or to determine the energy performance).

Assessment boundaries and weighting factors for the building, on-site, nearby and distant shall be established in a way to avoid double counting of renewable energy. Double counting of renewables in the energy supply chain to and from the building shall be prohibited.

The choice of energy weighting factors made SmartLivingEPC scheme correspond to those applicable in each national context. The choice regarding the inclusion or exclusion of energy contribution to the perimeter (origin) depending on the calculation objective is also that applicable in each national context.

Table 6. Output data. Overarching preparation steps

Description	Identifier	Unit	Component of origin	Component of destination
Both assessments at the building-level and complex level				
Assessment case	CASE_IDENTIFIER	n/a	Any	all
Object type	SLE_OBJECT_TYPE	n/a	Any	all
Application type	SLE_APPLIC_TYPE	n/a	Any	all
Assessment type	SLE_ASSESS_TYPE	n/a	Any	all
For assessments at the building-level				
Building category[a]	BLDNGCAT_TYPE	n/a	Any	all
Space category for each space or group of spaces	SPACECAT_TYPE	n/a	Any	all
Type of combination of services[b]	SLE_LISTSERVICES_TYPE	n/a	Any	all
Reference size	SLE_REFSIZE	m^2	Any	all
[a] More than one choice in case of complex level assessment. [b] The overarching combination of services may be modified for each component.				

2.3 Asset assessment. Building level

2.3.1 Output data and Reporting

The output data of this assessment are listed in Table 7.

Table 7. Output data. Asset assessment. Building level

Description	Symbol	Unit	Component of origin	Component of destination
Total yearly output data				
Weighted energy performance	E_{we}	kWh/an $kgCO_2$/an $kgCO_{2eq}$/an €/an kWh/m²/an	Energy Performance	-
Renewable energy ratio	RER	-	Energy Performance	-
Energy available for use outside the building	$E_{exp;el;avl;an}$	kWh/an	Energy Performance	-
Yearly output data per service or per building zone				
Weighted energy performance per service or per zone or per service and zone	$E_{we;X}$ $E_{we;X;z}$	kWh/an $kgCO_2$/an $kgCO_{2eq}$/an €/an kWh/m²/an	Energy Performance	-
Renewable energy ratio per service	RER_X	-	Energy Performance	-
Delivered energy per service or per zone or per service and per zone	$E_{del;X}$ $E_{del;X;z;j}$	kWh/an	Energy Performance	-
Total smart readiness score	SR	%	Smart Readiness	-
Smart readiness score per key functionality	SR_f	%	Smart Readiness	-
Smart readiness score per impact criterion	SR_{ic}	%	Smart Readiness	-
Smart readiness score per technical domain	SR_d	%	Smart Readiness	-
PMV, per zone *z*	PMV	-	IEQ	-
PPD, per zone *z*	PPD	%	IEQ	-
Illuminance level	E_v	Lx	IEQ	-
Daylight factor	DF	%	IEQ	-
Colour Rendering Index	CRI	-	IEQ	-
Colour Temperature	CT	-	IEQ	-
Sound pressure, per frequency	L_p	dB	IEQ	-
Global Sound pressure	$L_{p;g}$	dB (A)	IEQ	-
Reverberation time	RT60	sec.	IEQ	-
CO_2 concentration, per zone *z*	$[CO_2]$	ppm	IEQ	-
Lifecycle **Global Warming Potential**	GWP	$kgCO_{2eq}/m^2$	IEQ	-

Lifecycle **Global Warming Potential**		$kgCO_{2eq}/kg$	Sustainability	-
Lifecycle **Ozone depletion potential**	ODP	$kgCFC11_{eq}$	Sustainability	-
Lifecycle **Acidification potential**	AP	$kgSO_{2eq}/kg$	Sustainability	-
Lifecycle **Eutrophication aquatic freshwater**	EP	kg $[PO_4]^{3-}{}_{eq}$	Sustainability	-
Lifecycle **Eutrophication aquatic marine**	EP	kgN_{eq}	Sustainability	-
Lifecycle **Eutrophication terrestrial**	EP	$molN_{eq}$	Sustainability	-
Lifecycle **Photochemical ozone formation**		$kgEthen_{eq}$	Sustainability	-
Lifecycle **Depletion of abiotic resources – non-fossil resources**	$ADPE$	$kgSb_{eq}$	Sustainability	-
Lifecycle **Depletion of abiotic resources – fossil resources**	$ADPF$	MJ	Sustainability	-

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. Thus, there is a rating used for reporting each component's main output.

The total rating of each component is weighted to deliver the overall rating for the assessment type at a given scope. Thus, the SmartLivingEPC class is assigned to each assessed object based on the equivalence of Table 8.

Table 8. SmartLivingEPC class. Asset assessment. Building level.

Class	Score
A	≥90
B	≥80
C	≥65
D	≥50
E	≥35
F	≥20
G	≥0

2.3.2 Energy performance

SmartLivingEPC's energy component of the asset assessment at building level is based on the whole set of EPB standards, which constitute the standard series aimed at the international harmonisation of the methodology for assessing the energy performance of buildings.

2.3.2.1 Zoning

Assessed objects can be divided into thermal zones. Where possible, the assessed object is considered a single thermal zone for each service included in the assessment. For high performing buildings the interest in more precise energy performance assessment could be more important than for existing buildings with poor energy performance.

However, as indicated in EN ISO 52000-1, the energy performance calculation may require that the assessed object is divided into thermal zones depending on the differentiation in conditions of use over the spaces in the building, the complexity of the building and technical building systems (e.g., thermal mass, internal gains including system heat losses, glazing to floor area ratio, shading, orientation, etc.). A thermal zone is a part of the building that consists of a set of elementary spaces that share the same thermal balance. Then the thermal balance calculation is performed separately for each thermal zone and not directly for the whole assessed object.

The influence of technical building systems on the thermal balance, in the form of dissipated heat or cold, is considered per thermal zone.

SmartLivingEPC follows the linear sub-division approach. The complementary is true for the aggregation. If a quantity X shall be sub-divided or distributed to elements i according to the weighting factor Y, it will be as per **Equation 2**, where the weighting factor Y_i is a metric of the element i.

$$X_i = X \cdot \frac{Y_i}{\sum_i Y_i} \quad \textbf{Equation 2}$$

The total number of thermal zones cover the whole area of the assessed object. The thermal zoning also applies to thermally unconditioned spaces. Certain thermally unconditioned spaces may, for reasons of simplicity, be assumed to have the same conditions of use as the adjacent thermally conditioned spaces and then joined. Extensive discussion on this can be found in [1]. The choice whether these enclosed spaces are assumed to have the same conditions of use as the adjacent thermally conditioned spaces may have a very strong impact on the calculated energy performance. Also, the choice whether the size of these spaces is included in the size of the building

Most input, like most physical properties, boundary conditions and conditions of use, are not gathered at the level of the elementary spaces, but at the level of the thermal zones.

2.3.2.2 Output data

The output data of this assessment are listed in Table 9.

Table 9. Output data. Energy performance component. Asset assessment. Building level.

Description	Symbol	Unit	Component of destination
Total yearly output data			
Weighted energy performance	E_{we}	kWh/an $kgCO_2$/an $kgCO_{2eq}$/an €/an kWh/m²/an	-
Renewable energy ratio	RER	-	-
Energy available for use outside the building	$E_{exp;el;avl;an}$	kWh/an	-
Yearly output data per service or per building zone			
Weighted energy performance per service or per zone or per service and zone	$E_{we;X}$ $E_{we;X;z}$	kWh/an $kgCO_2$/an $kgCO_{2eq}$/an €/an kWh/m²/an	-
Renewable energy ratio per service	RER_X	-	-
Delivered energy per service or per zone or per service and per zone	$E_{del;X}$ $E_{del;X;z;j}$	kWh/an	-

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration.

In the SmartLivingEPC scheme the default energy rating method with a single reference point from [4] is used. Thus, the performance rating obtained is placed on a scale ranging from A (objects of best energy performance) to G (objects of worst energy performance), as described in section 2.3.2.6.

2.3.2.3 Calculation intervals and period

SmartLivingEPC calculated energy performance assessment opts for the monthly calculation interval (monthly quasi-steady-state method).

Regarding the cooling period, SmartLivingEPC performs the calculation over a year by default. Nevertheless, the length of the heating or cooling season is defined by the operation time of the respective technical systems. It may differ from the time resulting from the energy needs calculation.

2.3.2.4 Input data

Because of the modular structure of the EPB Standards, which constitute the methodological basis of the asset assessment's energy performance component, the input data is defined by each of the applicable standards described in detail in Table B.1 of [1].

2.3.2.5 Calculation procedure

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

1. Definition for the building category or, if differentiated, for each space category, of the internal conditions of use (e.g., temperature, humidity, occupancy, internal heat gains, time schedule thereof). SmartLivingEPC bases the internal conditions of use in those from the applicable standard in M1-6 (i.e., EN 16798-1 [5] and CEN/TR 16798-2 [6]).

   For each space the useful floor area shall be assessed. This is needed to quantify specific conditions for use that are expressed per surface unit and for the application of the simplifications and the zoning and (re-) allocation rules.

   In addition, for each space the air volume shall be assessed. This is needed as basis for the air volume per thermal zone.

2. Definition of the external conditions shall be defined according to the location. SmartLivingEPC relies on custom files generated based on PVGIS[2].
3. Partition the building in zones, if needed. The zoning may be different for the thermal energy need calculation and for technical building systems.
   The calculation direction goes from the needs to the source (e.g., from the building energy needs to the primary energy). Electrical energy (for lighting, ventilation, auxiliary) and thermal energy (for heating, cooling, humidification, dehumidification, domestic hot water) are considered separately inside the assessment boundaries. Cooling quantities shall be positive when heat is extracted from the space and/or system.
4. For each calculation interval, calculation of the energy needs for heating, cooling, and (de)humidification and domestic hot water. For each of the technical building systems related to the services included in the assessment, calculation of the energy use, including auxiliary energy, and the contribution of renewable energy sources (e.g., thermal energy generated by solar thermal collectors for domestic hot water). The recoverable thermal losses are not included in the assessment. All this considers the impact of building automation and control.
5. Calculate PV, wind, CHP and other electricity on-site production.
6. Calculate delivered and exported energy component for each calculation interval.
   The assessment boundary is related to the assessed object, determined as part of the overarching preparation steps of section 2.2.2.
   As indicated in EN ISO 52000-1, energy can be imported or exported through the assessment boundary. The assessment boundary defines where the actual value of the delivered or exported energy is evaluated. The delivered energies are classified according to the following perimeters that define the

[2] Accessible at https://re.jrc.ec.europa.eu/pvg_tools/en/

origin or destination: on-site, nearby, and distant. Energy weighting factors are defined for each energy flow delivered or exported through the assessment boundary, considering the origin for the former and the destination for the latter. Furthermore, energy contribution based on the perimeter may be included or excluded for certain output indicators.

The weighted overall energy performance of the assessed object is the balance at the assessment boundary of the weighted delivered energy, required to meet the energy demand of considered uses and to generate the exported energy, and the weighted exported energy. As indicated in EN ISO 52000-1, the weighting shall be performed in each calculation interval to allow time dependent weighting factors.

The weighting energy performance can be calculated with any type of weighting, being the most common ones the primary energy, which can be non-renewable, renewable, and total; greenhouse gas emissions; and costs. The numerical value of the weighting factors may be different for energy delivered and exported. Furthermore, for exported energy, there are two complementary types of weighting factors for exported energy, they are based on:

- The resources used to produce the exported energy carrier, that are used for “Step A” evaluation. In this case, the weighting factors for a given energy carrier don’t vary depending on the destination of the exported energy but may be time dependent. The weighting factors shall be identified per energy carrier with a subscript.
- The resources avoided by the external grid due to the export of the energy carrier, that are used for “Step B” evaluation.

7. For each calculation interval, weighting delivered and exported energy, considering options such as inclusion or not of exported energy into the energy performance of the building.
8. Sum individual step (i.e., monthly) results and get the energy performance for the calculation period (i.e., annual).
9. Calculate the delivered and/or weighted energy per service of per part of a building according to Annex E in [3].
10. Calculate partial performance indicators.
Table A.21 in [3] serves as template for the choice or choices of the metric for the reference size. In addition, Table A.22 reflects the choice of space categories that are included in the metric for the building size. SmartLivingEPC defines the reference size as the gross area of the conditioned spaces. The reference size is useful for the normalisation of overall and partial indicators.
11. Provide a calculation report, including the rating as indicated in section 2.3.2.6.

2.3.2.6 Reporting

The main performance indicator for the energy performance component of SmartivingEPC scheme is non-renewable primary energy indicator.

SmartLivingEPC’s energy rating method is based on the default method with a single reference point indicated in [4]:

- The performance scale ranges from Class A to G.
- The boundaries of the classes are based on a nonlinear scale ($Y = \sqrt{2}^{(n-n_{ref})}$).
- The energy performance regulation reference, R_r, is placed at the boundary of classes 4 and 5 ($n_{ref} = 4$).
- A percentual score is assigned based on the ratio between the energy performance of the assessed object (EP) and the energy performance regulation reference (R_r) based on a polynomial function ($EP_{score} = -1{,}5833 \left(\frac{EP}{R_r}\right)^2 - 2{,}7298 \left(\frac{EP}{R_r}\right) + 99{,}936$).

Thus, the energy class is assigned to each assessed object based on the comparison to the applicable energy performance regulation reference based on the equivalence of

Table 10. In addition to the energy class, a percentual score is assigned.

Table 10. SmartLivingEPC Energy performance class. Asset assessment. Building level.

EP Class	EP Score	Relative to reference
		$EP < 0$
A	100	$0\ R_r < EP \leq 0{,}35\ R_r$
B	82,5	$0{,}35\ R_r < EP \leq 0{,}50\ R_r$
C	75	$0{,}50\ R_r < EP \leq 0{,}71\ R_r$
D	64,5	$0{,}71\ R_r < EP \leq 1{,}00\ R_r$
E	50	$1{,}00\ R_r < EP \leq 1{,}41\ R_r$
F	29,45	$1{,}41\ R_r < EP \leq 2{,}00\ R_r$
G	0	$2{,}00\ R_r < EP$

2.3.3 Smart readiness

SmartLivingEPC's smartness component of the asset assessment at building level is based on the methodology outlined by the Commission Delegated Regulation 2020/2155 [7], considering the smart-ready service catalogue and weighting factors proposed by the European Commission through the SRI Support Team SRI (SRI assessment package - v4.5 being the latest [8].

2.3.3.1 Output data

The output data of this assessment are listed in Table 11.

Table 11. Output data. Smartness Component. Asset assessment. Building level

Description	Symbol	Unit	Component of destination
Total smart readiness score	SR	%	-
Smart readiness score per key functionality	SR_f	%	-
Smart readiness score per impact criterion	SR_{ic}	%	-
Smart readiness score per technical domain	SR_d	%	-

2.3.3.2 Calculation intervals and period

The nature of SmartLivingEPC calculated smartness assessment does not require the definition of a calculation interval or period.

2.3.3.3 Input data

Performing an SRI assessment requires the identification of general information of the assessed object as well as retrieving the inputs needed for the calculations. In addition, information related to administrative aspects of the assessment are required, similarly to that required for the of energy performance assessment. However, the input data required for the core methodology is listed in Table 12.

Table 12. Input data. Smartness Component. Asset assessment. Building level

Description	Symbol	Unit	Range	Origin	Varying
Preferred SRI weighting factors	n/a	-	Only Method B is supported	Various	No
Preferred SRI service catalogue	n/a	-	Only Method B is supported	Various	No
Presence of technical domain d		-	1-0	Various	No
Applicability of smart-ready service $S_{i,d}$	fa_s	-	1-0	Various	No
Main functionality level of smart-ready service $S_{i,d}$	$FL1(S_{i,d})$	-	LIST[a]	Various	No
Share of applicability of Main functionality level of smart-ready service $S_{i,d}$	$fs1\left(FL1(S_{i,d})\right)$	%	0-100	Various	No
Secondary functionality level of smart-ready service $S_{i,d}$	$FL2(S_{i,d})$	-	LIST[a]	Various	No
Share of applicability of Secondary functionality level of smart-ready service $S_{i,d}$	$fs2\left(FL2(S_{i,d})\right)$	%	0-100	Various	No

2.3.3.4 Calculation procedure

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

1. Definition of the climate zone according to the location.
2. For each technical domain, identification of its presence in the assessed object.
3. For each applicable technical domain, identification of the applicability of each smart-ready service.
4. For each applicable smart-ready service, identification of the main functionality level and the share of assessed object covered by it. In case of an additional functionality level per smart-ready service repeat the process with the secondary.
5. Calculate the score per technical domain and impact criterion considering the related scores per each smart-ready service's functionality level.
6. Calculate the maximum score per technical domain and impact criterion considering the related scores per each smart-ready service's functionality level.
7. Calculate the smart readiness score per technical domain and impact criterion.
8. Sum the scores per technical domain considering their respective contribution to each impact criterion. Divide the result by the maximum possible score to obtain the smart readiness score per impact criterion (SR_{ic}).
9. Repeat the process per impact criterion, considering the respective contribution from each technical domain, to obtain the smart readiness core per technical domain (SR_d).
10. Obtain the smart readiness score per functionality (SR_f) by doing the weighted sum of scores per impact criterion.
11. Obtain the total smart readiness score (SR) by doing the weighted sum of scores per functionality.

2.3.3.5 Reporting

The main performance indicator for the smartness component of SmartLivingEPC scheme is the total smart readiness score.

SmartLivingEPC's smartness rating method is based on the methodology indicated in [7]:

- The performance rating is based on seven classes; namely, 90-100%; 80-90%; 65-80%; 50-65%; 35-50%; 20-35%; <20%, ranging from highest to lowest smart readiness.

2.3.4 Indoor Environmental Quality

The indoor environmental quality dimension of the SmartLivingEPC asset assessment for buildings or building units is rooted in M1-6 module of the set of EPB standards [9]. As indicated in[3], the related standards are EN 16798-1, CEN/TR 16798-2, ISO 17772-1, and ISO/TR 17772-2. Consequently, in SmartLivingEPC asset assessment the IEQ of buildings or building units addresses four areas: thermal comfort, visual comfort – lighting, acoustic comfort, and indoor air quality.

Additional non-energy parameters are considered to be included in the SmartLivingEPC asset assessment, such as accessibility, earthquake seismic class, and water efficiency indicators.

2.3.4.1 Zoning

Calculating indoor environment quality parameters in every room of a building might seem ideal for a comprehensive assessment, but several considerations make it impractical. The time required for planning and data analysis, and logistical challenges are significant factors that limit the feasibility of such widespread assessment. Therefore, a strategic approach is essential to optimize resource allocation and prioritize rooms for IEQ calculations.

By carefully selecting zones for IEQ assessment based on factors such as occupancy, room typology, and other relevant criteria, a representative sample can be obtained that captures the variability of IEQ conditions. This approach optimizes resources in terms of both cost and time while still delivering valuable insights into the building's overall indoor air quality profile.

When selecting a limited number of rooms for IEQ measurements in buildings, several criteria can be considered to ensure a representative sample, such as those described by Wargocki et al. [10]. These criteria include, but are not limited to:

- **Representative Rooms**: To ensure the assessment reflects realistic IEQ conditions, prioritize selecting rooms that are actively occupied. Occupancy can affect indoor pollutant generation and ventilation rates, thus influencing IEQ parameters. It is important to select rooms with the lowest and highest occupation density. This allows for an assessment of IEQ conditions under varying occupancy levels, which can significantly influence air quality.
- **Geographic Orientations**: Rooms with different geographic orientations should be chosen. This ensures that IEQ measurements capture potential variations in sunlight exposure, airflow patterns, and outdoor pollutant infiltration, which can differ depending on a room's orientation.
- **Street/Road and Garden-Facing Rooms**: Selecting rooms facing different environments, such as streets, roads, and gardens, helps evaluate the impact of outdoor pollution sources and vegetation on IEQ. These different settings can introduce diverse pollutant profiles and airflow characteristics.
- **Typologies of Rooms**: It is important to include rooms with different typologies, which may include:
    - Rooms built or retrofitted during the same period: This accounts for potential differences in building materials, ventilation systems, and overall IEQ performance based on construction practices during specific periods.
    - Rooms sharing the same air handling unit and ventilation/air conditioning zone: This allows for assessing IEQ similarities and differences within the same controlled environment.
    - Rooms with similar building materials and furniture: Similar materials and furniture can affect IEQ through emissions of volatile organic compounds (VOCs) and other pollutants.
    - Rooms with similar types of solar shading devices: Solar shading devices can impact thermal conditions and air circulation, which can influence IEQ.
    - Specific Room Types: Buildings with office spaces, including both single and open-plan offices, allow for evaluating IEQ in different work environments. In hotels or similar establishments, selecting rooms of various sizes provides insights into IEQ variations across different guest accommodations.

By considering these room selection criteria, the IEQ measurements will provide a representative overview of the building's indoor environment, accounting for numerous factors that contribute to air quality variations. SmartLivingEPC recommends performing the assessment in, at least, four reference zones, which shall strive to represent the different areas of the building (e.g., orientation, facing street or inner courtyards, floor, usage, etc.) [11].

2.3.4.2 Thermal Comfort

A human being's thermal sensation is mainly related to the thermal balance of his or her body as a whole. Thermal balance is obtained when the internal heat production in the body is equal to the loss of heat to the environment. In a moderate environment, the human thermoregulatory system will automatically attempt to modify skin temperature and seat secretion to maintain heat balance. This balance is influenced by physical activity and clothing, as well as the environmental parameters: air temperature, mean radiant temperature, air velocity and air humidity. When these factors are known, it is possible to estimate the thermal dissatisfaction. Thermal dissatisfaction can be caused by people feeling too warm or too cold in a given environment. Thermal discomfort can also be caused by unwanted local cooling or heating of the body. The most common local discomfort factors are radiant temperature asymmetry (i.e., cold, or warm surfaces), draught (i.e., local cooling of the body caused by air movement), vertical air temperature difference, and cold or warm floors [12].

2.3.4.2.1 Output data

The main indicators to evaluate the thermal comfort are Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) per zone, as described in Table 13.

Table 13. Output data. IEQ component. Thermal Comfort. Asset assessment. Building level.

Description	Symbol	Unit	Component of destination
PMV, per zone *z*	PMV	-	-
PPD, per zone *z*	PPD	%	-

The Predicted Mean Vote (PMV) index as defined in EN ISO 7730 predicts the mean value of the votes of a large group of people on the 7-point thermal sensation scale, based on the heat balance of the human body. Additionally, the Predicted Percentage Dissatisfied (PPD) index can also be used, as a derivative of the PMV index also defined in [12], to obtain a quantitative percentage of thermally dissatisfied people who feel too cool or too warm. In addition to the main output indicators listed in Table 13, there are variables and parameters used in the calculations (e.g., operative temperature) which may also be reported.

The numeric indicators above do not yet automatically reveal the quality of the assessed zone with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, the thermal comfort category obtained is as described in section 2.3.4.2.5.

Both the indicators and ratings obtained at per zone can be aggregated to the assessed object.

2.3.4.2.2 Calculation intervals and period

SmartLivingEPC calculated thermal comfort is not calculated dynamically by default but rather assessed for the worst-case scenario in terms of outdoor air temperature.

2.3.4.2.3 Input data

The input data listed in Table 14 is needed per zone. Geometric and constructive information of the building (e.g., envelope surface area, thermal resistance coefficients), information on the building occupation and operating conditions (e.g., occupancy details), and on the external environmental conditions (e.g., outdoor air temperature) is required. However, they are assumed to be provided by other modules, concretely M2, M1-6, M1-13 as indicated in Table 3, respectively.

General information such as the number of floors and the identification of the zones to be assessed (e.g., rooms ID in non-residential buildings) should also be provided. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 14. Input data. IEQ component. Thermal Comfort. Asset assessment. Building level.

Name	Symbol	Unit	Range	Origin*	Varying
Space category, per zone z^a		LIST		Various, M1-1	No
Occupancy, per zone z^a	Occ	-	0-1	Various, M1-6	Yes
Average **metabolic rate**, per zone *z*	M	met		Assessor input, M1-6	Yes
Average **clothing factor**, per zone *z*	I_{cl}	clo	0…5	Assessor input, M1-6	Yes
Dry-bulb room temperature, per zone *z*	θ_a	°C	10…30	M2-2, M2-3	Yes
Mean radiant temperature, per zone *z*	$\theta_{int;r;mn}$	°C	10…40	M2-2, M2-3	Yes
Relative air velocity, per zone *z*	v_{ar}	m/s	0…1	Assessor input, M1-6	Yes
Water vapour partial pressure, per zone *z*	p_a	Pa	0…2700	M2-2, M2-3	Yes
Convective heat transfer coefficient, per zone *z*	h_c	W/(m²·K)	0…50	M2-5.1	Yes

* When a module is listed, it is referred to the codification of the EPB Standards.

The metabolic rate can be estimated using ISO 8996 [13] or Annex B in [12], considering the type of work. For varying metabolic rates, a time-weighted average should be estimated during the previous 1 h period. Estimate the thermal resistance of clothing and chairs using ISO 9920 [14] or Annex C in [12], considering the time of year.

As indicated in [5], assumptions regarding clothing level and activity level shall be listed. For additional information on clothing see EN ISO 9928 and on activity see EN ISO 8996 [13].

The air velocity in the space is assumed to be < 0.1 m/s. The relative air velocity caused by body movement is estimated to be zero for a metabolic rate less than 1 met and equal to 0.3·(M-1) met otherwise.

2.3.4.2.4 Calculation procedure

1. Definition for the building category or, if differentiated, for each space category, of the internal conditions of use (e.g., temperature, humidity, occupancy, metabolism, time schedule thereof). For this component, SmartLivingEPC refers to the internal conditions defined in EN 16798-1.

   For each space the useful floor area shall be assessed. This is needed to quantify specific conditions for use that are expressed per surface unit and for the application of the simplifications and the zoning and (re-) allocation rules.

   In addition, for each space the air volume shall be assessed. This is needed as basis for the air volume per thermal zone.

2. Definition of the external conditions (e.g., outdoor air temperature) shall be defined according to the location. For this component, SmartLivingEPC refers to the climatic data used for energy performance calculations.
3. Partition the building in zones, if needed.
4. Calculation of the PMV and PPD following [12] per zone.

   PMV may be calculated for different combinations of metabolic rate, clothing insulation, air temperature, mean radiant temperature, air velocity and air humidity [15].

   In Annex E in [12] graphics of PMV values are given for different combinations of activity, clothing, operative temperature, and relative velocity.

   The calculation procedure for the PPD index is indicated in [12].

   The PMV and PPD indexes are derived from steady-state conditions but can be applied with good approximation during minor fluctuations of one or more of the variables, provided that time-weighted averages of the variables during the previous 1h are applied.

5. Provide a calculation report, including the rating as indicated in section 2.3.4.2.5.

2.3.4.2.5 Reporting

The main performance indicator for the thermal comfort component of SmartLivingEPC scheme is the total thermal comfort score ($TC_{score;z}$). The thermal comfort score is calculated following **Equation 3**.

$$TC_{score;z} = -1.0216 \cdot PPD + 101.54 \quad \textbf{Equation 3}$$

SmartLivingEPC's thermal comfort rating method is based on the following:

- The performance scale ranges from Class A to G.

Thus, the thermal comfort class is assigned to each assessed object based on the equivalence of Table 15.

Table 15. SmartLivingEPC. IEQ Component. Thermal comfort performance class. Asset assessment. Building level.

TC Class	TC Score
A	100
B	≥90
C	≥80
D	≥65
E	≥50
F	≥35
G	<20%

The score and rating can be expressed at the level of the assessed object by performing a volumetric weighted average.

2.3.4.3 Visual Comfort

Visual comfort describes the nature of the visual environment, which significantly impacts occupant well-being. In a poor visual environment, occupants may experience eye strain, headaches and fatigue. Visual comfort can be correlated with elements like illumination, glare, and colour. When these factors are known, it is possible to estimate the visual dissatisfaction, which can be caused by low visibility, excessive brightness and contrast, and light colour.

2.3.4.3.1 Output data

The main indicators to evaluate the visual comfort are the illuminance level, daylight factor, colour rendering index, and colour temperature, as listed in Table 16.

Table 16. Output data. IEQ component. Visual Comfort. Asset assessment. Building level.

Description	Symbol	Unit	Component of destination
Illuminance level	E_v	Lx	-
Daylight factor	DF	%	-
Colour Rendering Index	CRI	-	-
Colour Temperature	CT	-	-

The illuminance level indicates the brightness in a given indoor environment. The daylight factor is the ratio of the indoor daylight illuminance at a point within the enclosure to the outdoor illuminance at that point under the same unobstructed overcast sky. The Colour Rendering Index and Colour Temperature refer to the visual quality provided by a given luminaire.

The numeric indicators above do not yet automatically reveal the quality of the assessed zone with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, the visual comfort category obtained as described in section 2.3.4.3.5.

Both the indicators and ratings obtained at per zone can be aggregated to the assessed object.

2.3.4.3.2 Calculation intervals and period

SmartLivingEPC calculated visual comfort is not calculated dynamically by default, but rather for specific cases.

2.3.4.3.3 Input data

The input data listed in Table 17 is needed per zone. Geometric and constructive information of the building (e.g., type of glazings), on the lighting system (e.g., type of luminaires, etc.) and on the external environmental conditions (e.g., daylight parameters) is required. However, they are assumed to be provided by other modules, concretely M2, and M1-13 as indicated in Table 3, respectively.

General information such as the number of floors and the identification of the zones to be assessed (e.g., rooms ID in non-residential buildings) should also be provided. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 17. Input data. IEQ component. Visual Comfort. Asset assessment. Building level.

Name	Symbol	Unit	Range	Origin*	Varying
Average **luminous flux,** per zone *z*	I_{cl}	Lm	0…∞	Assessor input, M9	No
Average **Maintenance factor,** per zone *z*	LMF	-	0…1	Assessor input, M2	No
Average **Transparency coefficient,** per zone *z*		-	0…1	Assessor input, M2	No
Average **Colour Temperature,** per zone *z*	CT	-	0…∞	Assessor input, M9	No
Average **Colour Rendering Index,** per zone *z*	CRI	%	0…100	Assessor input, M9	No

Average **Electric power used in luminaires,** per zone *z*	W_{lum}	W	0…∞	Assessor input, M9	No
* When a module is listed, it is referred to the codification of the EPB Standards.					

For the assessor input parameters, the default values reproduced in Table 18 can be used for the purpose of methodological demonstration, in absence of EU-wide standardised or recognised alternatives.

Table 18. Default values for the T coefficient per window type

Window type	Transparency coefficient value
Single	0,97
Double glazing wood frame - old	0,95
Double glazing - PVC/Al - new	0,85
Double glazing - PVC/Ai - low e	0,7
Triple glazing	0,65
Triple glazing - low e	0,35

Table 19. Default values for the Luminous flux per luminaire type

Luminaire type	Luminous Flux value
Tungsten incandescent light bulb	15
Halogen lamp	20
Fluorescent lamp	60
LED lamp	90
Metal halide lamp	87
High pressure sodium vapor lamp	117
Low pressure sodium vapor lamp	150
Mercury vapor lamp	50

The target values for each of the indicators, as defined in EN 12464-1:2021 shall also be used.

2.3.4.3.4 Calculation procedure

1. Definition for the building category or, if differentiated, for each space category, of the target values for each of the indicators.

   For each space the useful floor area shall be assessed. This is needed to quantify specific conditions for use that are expressed per surface unit and for the application of the simplifications and the zoning and (re-) allocation rules.

2. Partition the building in zones, if needed.
3. Calculation of the illuminance [16] and daylight factor [16] per zone.
4. Provide a calculation report, including the rating as indicated in section 2.3.4.3.5.

2.3.4.3.5 Reporting

The main performance indicator for the visual comfort component of SmartLivingEPC scheme is the total visual comfort score ($VC_{score;z}$) per zone, which is composed by an addition of the partial visual comfort scores obtained per output indicator. They are calculated following:

$$VC_{score} = VC_{score;illuminance} + VC_{score;daylight} + VC_{score;CT} + VC_{score;CRI} \quad \text{Equation 4}$$

$$VC_{score;illuminance} = \frac{Illuminance}{Illuminance_{Target}} \quad if\ VC_{score;illuminance} \geq 1 \ then\ VC_{score;illuminance} = 1 \quad \text{Equation 5}$$

$$VC_{score;daylight} = \frac{Daylight}{Daylight_{Target}} \quad if\ VC_{score;daylight} \geq 1 \ then\ VC_{score;daylight} = 1 \quad \text{Equation 6}$$

$$VC_{score;CT} \quad if\ CT = CT_{Target}, then\ VC_{score;CT} = 1 \ else\ VC_{score;CT} = 0{,}5 \quad \text{Equation 7}$$

$$VC_{score;CRI} = \frac{CRI}{CRI_{Target}} \quad if\ VC_{score;CRI} \geq 1 \ then\ VC_{score;CRI} = 1 \quad \text{Equation 8}$$

SmartLivingEPC's visual comfort rating method is based on the following:

- The performance scale ranges from Class A to G.

Thus, the visual comfort class is assigned to each assessed object based on the equivalence of Table 20.

Table 20. SmartLivingEPC. IEQ Component. Visual comfort performance class. Asset assessment. Building level.

VC Class	VC Score
A	100
B	≥90
C	≥80
D	≥70
E	≥60
F	≥50
G	<50%

The score and rating can be expressed at the level of the assessed object by performing a surface weighted average.

2.3.4.4 Acoustic Comfort

In the field of building acoustics, several international standards provide critical guidance for evaluating and optimizing the acoustic performance of buildings. **EN 12354, Building Acoustics – Estimation of Acoustic Performance of Buildings from the Performance of Elements,** offers a comprehensive methodology for predicting the overall acoustic performance of a building based on the individual characteristics of its components, such as walls, floors, and ceilings. Complementing this, **ISO 717, Acoustics – Rating of Sound Insulation in Buildings and Building Elements,** provides a standardized framework for classifying and rating the sound insulation performance of different building materials and systems. For workplace environments, **ISO 11690,: Acoustics – Recommended Practice for the Design of Low-Noise Workplaces,** provides essential guidelines for creating acoustically comfortable workspaces.

2.3.4.4.1 Output data

The main indicators to evaluate the acoustic comfort are the sound pressure per frequency, global sound pressure and reverberation time, as listed in Table 21.

Table 21. Output data. IEQ component. Acoustic Comfort. Asset assessment. Building level.

Description	Symbol	Unit	Component of destination
Sound pressure, per frequency	L_p	dB	-
Global Sound pressure	$L_{p;g}$	dB (A)	-
Reverberation time	RT60	sec.	-

The sound pressure in decibels (A) expresses the sound level perceived by the human ear.

The numeric indicators above do not yet automatically reveal the acoustic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, the thermal comfort category obtained as described in section 2.3.4.4.5.

Both the indicators and ratings obtained at per zone can be aggregated to the assessed object.

2.3.4.4.2 Calculation intervals and period

SmartLivingEPC calculated acoustic comfort is not calculated dynamically by default but rather assessed for the worst-case scenario in terms of outdoor noise.

2.3.4.4.3 Input data

The input data listed in Table 22 is needed per zone. In addition, geometric and constructive information of the building (e.g., building category, dimensions of zone envelope, mass and sound absorption coefficient of opaque elements, type of glazings, etc.), and on the external environmental conditions (e.g., outdoor noise, etc.) is required. However, they are assumed to be provided by other modules, concretely M2, and M1-13 as indicated in Table 3, respectively.

General information such as the number of floors and the identification of the zones to be assessed (e.g., rooms ID in non-residential buildings) should also be provided. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 22. Input data. IEQ component. Acoustic Comfort. Asset assessment. Building level.

Name	Symbol	Unit	Range	Origin*	Varying
Average **Sound transmission attenuation**, per frequency and zone *z*	R_w	dB	0…∞	Various, M2	No
Average **Sound transmission attenuation**, per frequency and zone *z*	R_w	dB	0…∞	Various, M2	No
Outdoor Sound pressure level, per frequency	$L_{p;out}$	dB	0…∞	Assessor input, M1-13	No
* When a module is listed, it is referred to the codification of the EPB Standards.					

For the assessor input parameters, the default values reproduced in Table 18 can be used for the purpose of methodological demonstration, in absence of EU-wide standardised or recognised alternatives.

Table 23. Default values for the outdoor sound pressure level per frequency

Road type	Frequency (Hz)							
	31,5	63	125	250	500	1000	2000	4000
Large boulevard	80	98,7	91,6	86,4	82,7	80	77,7	75,9
Medium boulevard	70	90,8	82,9	77,1	73	70	67,5	65,7
Normal street	65	86,8	78,5	72,4	68,1	65	62,5	60,5
Narrow street	60	82,9	74,2	67,8	63,2	60	57,4	55,4

The target values for each of the indicators, as defined in [17], [18], [19] shall also be used.

2.3.4.4.4 Calculation procedure

1. Definition for the building category or, if differentiated, for each space category, of the target values for each of the indicators.

   For each space the useful floor area shall be assessed. This is needed to quantify specific conditions for use that are expressed per surface unit and for the application of the simplifications and the zoning and (re-) allocation rules.

2. Partition the building in zones, if needed.
3. Calculation of the indoor sound pressure level per frequency and global, and reverberation time per zone following [18], [19] per zone.
4. Provide a calculation report, including the rating as indicated in section 2.3.4.4.5.

2.3.4.4.5 Reporting

The main performance indicator for the acoustic comfort component of SmartLivingEPC scheme is the total acoustic comfort score ($AC_{score;z}$) per zone, which is composed by an average of the partial acoustic comfort scores obtained per output indicator. They are calculated following:

$$AC_{score} = \frac{AC_{score;sou.press.} + AC_{score;sou.press.;db(A)} + AC_{score;RT60}}{3}$$ **Equation 9**

$$AC_{score;sou.press.;f} = \frac{Sound\ pressure_f}{Sound\ pressure_{f;Target}} \qquad \begin{array}{l} if\ AC_{score;sou.press.;f} \geq 1 \\ then\ AC_{score;sou.press.;f} = 1 \end{array}$$ **Equation 10**

$$AC_{score;sou.press.} = \frac{\sum_f^{N_f} AC_{score;sou.press.;f}}{N_f}$$ **Equation 11**

$$AC_{score;sou.press.;db(A)} = \frac{Sound\ pressure_{db(A)}}{Sound\ pressure_{db(A);Target}} \qquad \begin{array}{l} if\ AC_{score;sou.press.;db(A)} \geq 1 \\ then\ AC_{score;sou.press.;db(A)} = 1 \end{array}$$ **Equation 12**

$$AC_{score;RT60} = \frac{RT60}{RT60_{Target}} \qquad \begin{array}{l} if\ AC_{score;RT60} \geq 1 \\ then\ AC_{score;RT60} = 1 \end{array}$$ **Equation 13**

The main performance indicator for the acoustic comfort component of SmartLivingEPC scheme is the total acoustic compliance score at the assessed object level.

SmartLivingEPC's acoustic comfort rating method is based on the following:

- The performance scale ranges from Class A to G.

Thus, the visual comfort class is assigned to each assessed object based on the equivalence of Table 24.

Table 24. SmartLivingEPC. IEQ Component. Acoustic comfort performance class. Asset assessment. Building level.

Class	Acoustic Compliance Score
A	100
B	≥90
C	≥80
D	≥70
E	≥60
F	≥50
G	<50%

The score and rating can be expressed at the level of the assessed object by performing a surface weighted average.

2.3.4.5 Indoor Air Quality

2.3.4.5.1 Output data

The main indicator to evaluate the Indoor Air Quality (IAQ) is the CO_2 concentration, as listed in Table 25.

Table 25. Output data. IEQ component. IAQ. Asset assessment. Building level.

Description	Symbol	Unit	Component of destination
CO_2 concentration, per zone *z*	$[CO_2]$	ppm	-

The numeric indicators above do not yet automatically reveal the quality of the assessed zone with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, the thermal comfort category obtained as described in section 2.3.4.5.5.

Both the indicators and ratings obtained at per zone can be aggregated to the assessed object.

2.3.4.5.2 Calculation intervals and period

SmartLivingEPC calculated air quality assessment opts for the hourly calculation interval.

Regarding the period, SmartLivingEPC performs the calculation over a two-week by default.

2.3.4.5.3 Input data

The input data listed in in Table 26 is needed per zone. Geometric and constructive information of the building (e.g., building category, dimensions of zone envelope, wind exposure, opaque and transparent air tightness), and on the external environmental conditions (e.g., outdoor CO_2 concentration, wind velocity) is required. However, they are assumed to be provided by other modules, concretely M2, and M1-13 as indicated in Table 3, respectively

General information such as the number of floors and the identification of the zones to be assessed (e.g., rooms ID in non-residential buildings) should also be provided. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 26. Input data. IEQ component. IAQ. Asset assessment. Building level.

Name	Symbol	Unit	Range	Origin*	Varying
Space category, per zone *z*[a]		LIST	n/a	Various, M1-1	No

Occupancy, per zone z[a]		-	0-1	Various, M1-6	Yes
Average **metabolic rate**, per zone z	M	met		Assessor input, M1-6	Yes
Average **Air infiltration rate** at 4 Pa, per zone z		ach	0…∞	Various	No
Mechanical ventilation outdoor air flow rate, per zone z	$\dot{V}_{out}$	m^3/h	0…∞	Various, M5	Yes
[a] When the information can't be obtained at zone level, building level parameters may be used. * When a module is listed, it is referred to the codification of the EPB Standards.					

The target values for each of the indicators, as defined in [5], [20] shall also be used.

2.3.4.5.4 Calculation procedure

1. Definition for the building category or, if differentiated, for each space category, of the target values for each of the indicators.

   For each space the useful floor area shall be assessed. This is needed to quantify specific conditions for use that are expressed per surface unit and for the application of the simplifications and the zoning and (re-) allocation rules.

   In addition, for each space the air volume shall be assessed. This is needed as basis for the air volume per thermal zone.
2. Definition of the external conditions (e.g., outdoor CO_2 concentration, wind velocity) shall be defined according to the location. For this component, SmartLivingEPC refers to the climatic data used for energy performance calculations.
3. Partition the building in zones, if needed.
4. For each calculation interval, assessment of the indoor CO_2 balance, considering the infiltration rate, mechanical ventilation fresh air flow rate, and CO_2 exhaled by occupants per zone according to. As a result, the CO_2 concentration in the zone for each calculation interval is obtained.
5. Perform time average sum of individual step results and get the air quality per zone for the calculation period.
6. Provide a calculation report, including the rating as indicated in section 2.3.4.5.5.

2.3.4.5.5 Reporting

The main performance indicator for the IAQ component of SmartLivingEPC scheme is the IAQ score ($IAQ_{score;z}$). It is calculated as follows:

$$IAQ_{score;z} = \frac{CO_{2_{Target}}}{CO_{2_z}} \qquad if\ IAQ_{score;z} \geq 1 \quad then\ IAQ_{score;z} = 1$$

Equation 14

The main performance indicator for the air quality component of SmartLivingEPC scheme is the total air quality compliance score at the assessed object level.

SmartLivingEPC's air quality rating method is based on the following:

- The performance scale ranges from Class A to G.

Thus, the air quality class is assigned to each assessed object based on the equivalence of Table 20.

Table 27. SmartLivingEPC. IEQ Component. Air Quality performance class. Asset assessment. Building level.

Class	IAQ Compliance Score
A	100
B	≥90
C	≥80
D	≥70
E	≥60
F	≥50
G	<50%

The score and rating can be expressed at the level of the assessed object by performing a volumetric weighted average.

2.3.5 Sustainability

The sustainability dimension of the SmartLivingEPC asset assessment for buildings or building units is rooted in Life Cycle Analysis (LCA) as described in Level(s)[3].

2.3.5.1 Output data

The output data of this assessment are environmental LCA indicators listed in Table 28. The indicators can be provided for many life cycle stages.

Table 28. Output data. Sustainability component. Asset assessment. Building level.

Description	Symbol	Unit	Component of destination
Lifecycle **Global Warming Potential**	GWP	$kgCO_{2eq}/m^2$	-
Lifecycle **Global Warming Potential**	GWP	$kgCO_{2eq}/kg$	-
Lifecycle **Ozone depletion potential**	ODP	$kgCFC11_{eq}$	-
Lifecycle **Acidification potential**	AP	$kgSO_{2eq}/kg$	-
Lifecycle **Eutrophication aquatic freshwater**	EP	$kg\ [PO_4]^{3-}{}_{eq}$	-
Lifecycle **Eutrophication aquatic marine**	EP	kgN_{eq}	-
Lifecycle **Eutrophication terrestrial**	EP	$molN_{eq}$	-
Lifecycle **Photochemical ozone formation**	POF	$kgEthen_{eq}$	-
Lifecycle **Depletion of abiotic resources – non-fossil resources**	$ADPE$	$kgSb_{eq}$	-
Lifecycle **Depletion of abiotic resources – fossil resources**	$ADPF$	MJ	-

[3] More information at https://environment.ec.europa.eu/topics/circular-economy/levels_en

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration.

The performance rating obtained shall be placed on a scale ranging from 100% (objects of best sustainability) to 0% (objects of worst sustainability).

In addition to the output indicators, valuable information is obtained as a result of the calculations (e.g., bill of quantities, materials, and lifespans). This information, albeit not formally constituting output indicators, shall be integrated into SmartLivingEPC's digital building logbook and Digital Twin.

2.3.5.2 Calculation intervals and period

The concept of calculation interval does not apply to SmartLivingEPC sustainability assessment.

Regarding the calculation period, SmartLivingEPC performs the calculation for many life cycle stages, identified with alpha numerical codes as indicated below:

- A1-A3. Construction materials.
    - Raw material supply (A1) includes emissions generated when raw materials are taken from nature transported to industrial units for processing. Loss of raw material and energy are also considered.
    - Transport impacts (A2) include exhaust emissions resulting from the transport of all raw materials from suppliers to the manufacturer's production plant as well as impacts on the production of fuels.
    - Production impacts (A3) cover the manufacturing of the production materials and fuels used by machines, as well as the handling of waste formed in the production processes at the manufacturer's production plants until the end-of-waste state.
- A4. Transportation to the site. It includes exhaust emissions resulting from the transport of building products from the manufacturer's production plant to the building site as well as the environmental impacts of the production of the used fuel.
- A5. Construction/installation process. It covers the exhaust emissions resulting from using energy during the site operations, the environmental impacts of production processes of fuel and energy and water, as well as handling of waste until the end-of-waste state.
- B1-B5. Maintenance and material replacement. It includes environmental impacts from replacing building products after they reach the end of their service life. The emissions cover impacts from raw material supply, transportation, and production of the replacing new material as well as the impacts from manufacturing the replacing material as well as handling of waste until the end-of-waste state.
- B6. Energy use. The considered use phase energy consumption impacts include exhaust emissions from any building-level energy production as well as the environmental impacts of production processes of fuel and externally produced energy. Energy transmission losses are also considered.
- B7. Water use. The considered use phase water consumption impacts include the environmental impacts of the production processes of fresh water and the impacts from wastewater treatment.
- C1-C4. Deconstruction. The impacts of deconstruction include impacts for processing recyclable construction waste flows for recycling (C3) until the end-of-waste stage or the impacts of pre-processing and landfilling for waste streams that cannot be recycled (C4) based on the type of material. Additionally, deconstruction impacts include emissions caused by waste energy recovery.
- D. External end-of-life impacts/benefits. The external benefits include emission benefits from recycling recyclable building waste. Benefits for re-used or recycled material types include the positive impact of replacing virgin-based material with recycled material and benefits for materials that can be recovered

for energy cover positive impact for replacing other energy streams based on average impacts of energy production.

2.3.5.3 Input data

Performing an LCA assessment requires the identification of general information of the assessed object (e.g., country) as well as retrieving the inputs needed for the calculations, particularly the Environmental Product Declaration (EPD) of materials used, as listed in Table 29. Some inputs are related to geometric and constructive information of the building (e.g., type and mass of materials used is required. Consequently, they may be provided by other modules, concretely M2.

Table 29. Input data. Sustainability Component. Asset assessment. Building level

Description	Symbol	Unit	Range	Origin	Varying
Type of material linked to building elements	n/a	-	List	M2, Various	No
Mass, per material linked to building elements	n/a	kg	0…∞	M2, Various	No
EPD, per material linked to building elements	n/a	-	-	Various	No

The EPD includes indicators such as ODP (Ozone Depletion Potential) [kg CFC11-Equivalent], AP (Acidification Potential) [kg SO_2-Equivalent], EP (Eutrophication Potential) [kg PO_4^{3-}-Equivalent], POCP (Photochemical Ozone Creation Potential) [kg ethene-Equivalent] and ADPF (Abiotic Depletion Potential for Fossil Fuels) [MJ].

2.3.5.4 Calculation procedure

1. Obtention of the types and mass of materials used in the building elements of the assessed object.
2. For each life cycle stage, establish a relationship between each type of material and the EDP.
3. Calculate the output indicators.
4. Apply the weighting factors to obtain the overall sustainability score.

2.3.5.5 Reporting

The main performance indicator for the sustainability component of SmartLivingEPC scheme is the total sustainability score. As there are no European standardized or widely accepted benchmarks, a rating has not been defined at the methodological level for this component.

2.4 Operational assessment. Building level

2.4.1 Output data and Reporting

The output data of this assessment is listed in Table 30.

Table 30. Output data. Operational assessment. Building level

Description	Symbol	Unit	Component of origin	Component of destination
Total yearly output data				
Weighted energy performance	E_{we}	kWh/an kgCO_2/an kgCO_{2eq}/an €/an kWh/m^2/an	Energy Performance	-
Renewable energy ratio	RER	-	Energy Performance	-
Energy available for use outside the building	$E_{exp;el;avl;an}$	kWh/an	Energy Performance	-
Yearly output data per service or per building zone				
Weighted energy performance per service or per zone or per service and zone	$E_{we;X}$ $E_{we;X;z}$	kWh/an kgCO_2/an kgCO_{2eq}/an €/an kWh/m^2/an	Energy Performance	-
Renewable energy ratio per service	RER_X	-	Energy Performance	-
Delivered energy per service or per zone or per service and per zone	$E_{del;X}$ $E_{del;X;z;j}$	kWh/an	Energy Performance	-
Total output data				
As designed energy cost	EC_d	€/m^2/an €/m^2/month	Finances	-
As operated energy cost	EC_o	€/m^2/an €/m^2/month	Finances	-
Predicted energy cost per *N* years	EC_p	€/m^2/N an	Finances	-
Payback Period	PBP	Years, months	Finances	-
Net Savings	NS		Finances	-
Savings-to-Investment Ratio	SIR		Finances	-
Output data per service or per energy carrier				
As operated energy cost per service or per energy carrier	$EC_{o;X}$	€/m^2/an €/m^2/month	Finances	-
Predicted energy cost per *N* years, per service or per energy carrier	$EC_{p;X;N}$	€/m^2/N an	Finances	-
Time spent in each Category, for thermal comfort, per zone z		h	IEQ	-
		% of total occupancy	IEQ	-

Description	Symbol	Unit	Component of origin	Component of destination
The percentage of time when temperature exceeds category limit for 1°C, for thermal comfort, per zone		% of total	IEQ	-
The percentage of time when temperature exceeds category limit for 2°C, for thermal comfort, per zone		% of total	IEQ	-
Time spent in each Category, for CO_2		h	IEQ	-
		% of total occupancy	IEQ	-
Time spent in each Category, for PM2,5		h	IEQ	-
		% of total occupancy	IEQ	-
Number of respondents in each Category, for thermal comfort, per zone *z* and respondent group *g*		people	IEQ	-
		% of total respondents	IEQ	-
Number of respondents in each Category, for IAQ per zone *z* and respondent group *g*		people	IEQ	-
		% of total respondents	IEQ	-
Number of respondents in each Category, for draught per zone *z* and respondent group *g*		people	IEQ	-
		% of total respondents	IEQ	-
Reproduction number	R	-	IEQ	-
NOTE *CAR_NAMEj is the name of energy carrier j*				

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. Thus, there is a rating used for reporting each component's main output.

The total rating of each component is weighted to deliver the overall rating for the assessment type at a given scope. Thus, the SmartLivingEPC class is assigned to each assessed object based on the equivalence of Table 31.

Table 31. SmartLivingEPC class. Operational assessment. Building level.

Class	Score
A	≥90
B	≥80
C	≥65
D	≥50
E	≥35
F	≥20
G	≥0

2.4.2 Energy performance

SmartLivingEPC's energy component of the operational assessment at building level is only applicable to existing buildings in the use phase. Any envisaged measured energy performance rating should be considered during the design phase of technical systems in new buildings.

As indicated in the overarching standard [3], the measured energy performance is calculated in the same way as the calculated energy performance using the measured delivered and exported energy amounts instead of the corresponding calculated amounts.

2.4.2.1 Output data

The output data of this assessment are listed in Table 32.

Table 32. Output data. Energy performance component. Operational assessment. Building level.

Description	Symbol	Unit	Component of destination
Total yearly output data			
Weighted energy performance	E_{we}	kWh/an $kgCO_2$/an $kgCO_{2eq}$/an €/an kWh/m^2/an	-
Renewable energy ratio	RER	-	-
Energy available for use outside the building	$E_{exp;el;avl;an}$	kWh/an	-
Yearly output data per service or per building zone			
Weighted energy performance per service or per zone or per service and zone	$E_{we;X}$ $E_{we;X;z}$	kWh/an $kgCO_2$/an $kgCO_{2eq}$/an €/an kWh/m^2/an	-
Renewable energy ratio per service	RER_X	-	-
Delivered energy per service or per zone or per service and per zone	$E_{del;X}$ $E_{del;X;z;j}$	kWh/an	-
NOTE *CAR_NAMEj is the name of energy carrier j*			

For operational assessments, there are a few considerations. The history of the energy delivery and export is seldom known. Only seasonal or yearly amounts are usually known. Also, the renewable energy ratio cannot be determined if the contribution of renewable sources cannot be measured. In addition, the availability of measured energy data for specific services and/or building zones depends on the number and quality of installed metering devices. Although some calculation procedures allow identification of the partial energy performance for specific services without a dedicated meter (e.g., reverse calculation method).

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration.

In the SmartLivingEPC scheme the default energy rating method with a single reference point from [4] is used. Thus, the performance rating obtained is placed on a scale ranging from A (objects of best energy performance) to G (objects of worst energy performance), as described in the relevant section.

2.4.2.2 Measurement intervals and period

As indicated in [3], the assessment period is the same as for the calculated energy performance. SmartLivingEPC defined, by default, a year.

The measurement interval is the time span between readings of meters or use of known amounts of energy. If there are several energy carriers and/or energy uses, measurement intervals can be asynchronous. SmartLivingEPC defines a daily measurement interval.

The measurement period is the interval of time covered by measurement intervals. To average out the effect of climate and/or user behaviour, the required measurement period may be a multiple of the calculation period. SmartLivingEPC defines an annual measurement period.

Validation criteria specify the required number of measurement intervals and the minimum required duration of the measurement period.

2.4.2.3 Input data

As indicated in EN ISO 52000-1, the input data required corresponds to operating conditions data of the technical (sub-)systems, which are given per metered energy flow instead of per generator and/or per sub-system as in the calculated energy performance. An overview is included in Table 33. In addition, information gathered in the Overarching preparation steps is also relevant.

Each sub assessment describes specific input data that should be gathered.

Table 33. Input data. Energy component. Operational assessment. Building level.

Name	Symbol	Unit	Range	Origin*	Varying
Measured electricity delivered for service(s) X	$E_{del;el;X;meas}$	kWh	0…∞	Various	Yes
Electricity use type	EL_USE	n.a.	LIST	Various	No
Measured electricity exported	$E_{exp;el;meas}$	kWh	0…∞	Various	Yes
Measured on-site electric energy produced by sub-system *j*	$E_{pr;el,j;meas}$	kWh	0…∞	Various	Yes
Electricity production type i	EL_PROD, i	n.a.	LIST	Various	No
Measured electric energy used in the building for non-EPB uses	$E_{nEPus;el;meas}$	kWh	0…∞	Various	Yes
Measured delivered energy carrier cr,i for building service(s) X	$E_{del;cr,i;X;meas}$	kWh	0…∞	Various	Yes
Delivered energy carrier i type	$MEAS\_CR, i$	n.a.	LIST	Various	No
Additional data required for the calculation of energy performance indicators per part of a building					

Measured energy use per part of a building z,i	$Q_{X;z,i;meas}$	kWh	0…∞	Various	Yes
Default weight per part of a building	$X_{def;i}$	kWh	0…∞	Various	Yes
* When a module is listed, it is referred to the codification of the EPB Standards. [a] When the information can't be obtained at zone level, building level parameters may be used. [b] Covering the same period as the sub-assessment measurements.					

2.4.2.4 Measurement procedure

The measured energy amount needs corrections and/or extrapolations for the following reasons [3]:

- **Energy services**: correct measured energy for services that are not included in the energy performance. *For example, the lighting or appliances energy use may be metered, while being excluded from the services included in the assessment.*
- **Estimation** of the amounts of fuel used if these are not automatically metered. *For example, weighting of the amount of humidity of wood, amount of coal or oil.*
- **Assessment period**: interpolation or extrapolation of the measurements to the assessment period (e.g., a full year), considering the different seasonal patterns for different services and renewable energy sources. This requires an estimation of the relative amounts and seasonal patterns if these energy flows are not known separately.
- **Weather**: correction from the actual to the standard weather, considering the differences in impact of weather on successive services and on renewable energy sources.
- **Occupancy and operation**: correction from actual to standard occupancy pattern and conditions of use.

EN ISO 52000-1 indicates that procedures for the measurement and correction of delivered and exported energy amounts are given in modules MX-10 of the set of EPB standards. However, not all technical building systems(M3-M11) reference an existing standard for submodule 10. In EN ISO 52000-2, only Heating (M3), Domestic Hot Water (M8), Lighting (M9) and BACS (M10) have one.

Although SmartLivingEPC fully acknowledges the need to define correction factors in order to deliver an operational energy performance assessment usable for certification applications, there are no standards yet defining such correction factors.

Nevertheless, the project is actively contributing to the activities within CEN/TC 371/WG 5 for the definition of the *Energy Performance of Buildings — Operational rating — Requirements for assessing Operational rating.*

2.4.2.5 Calculation of the energy performance based on measured

The assessment path is outlined in EN ISO 52000-1, and reproduced next:

1. The energy performance assessment based on measured energy starts with performing the overarching preparation steps, as described in section 2.2.2. This includes a comparison between the desired energy performance information (e.g., which services to rate and/or which parts of the building and/or which factors shall be neutralized).
   This step, performed in an existing building with no special provisions for metering, will provide limitations to the achievable results or the specification for the installation of additional metering devices.
2. Where relevant, and in connection with the pervious step, the details, boundaries and conditions of the assessed object are assessed.
3. The delivered and exported energy amounts are obtained according to the procedures given in the specific modules.

4. The measured energy performance is calculated according to clause 9.6 and 11 [3].
   For each calculation interval, weighting delivered and exported energy, considering options such as inclusion or not of exported energy into the energy performance of the building.
5. Sum individual step results and get the energy performance for the assessment period.
6. Obtain the delivered and/or weighted energy per service of per part of a building according to Annex E in [3].
7. Calculate partial performance indicators.

Provide a calculation report, including the rating as indicated in section 2.4.2.6.

2.4.2.6 Reporting

The main performance indicator for the energy performance component of SmartLivingEPC scheme is the total Weighted energy performance. As there are no European standardized or widely accepted benchmarks, a rating has not been defined at the methodological level for this component.

2.4.3 Finance

SmartLivingEPC's smartness component of the operational assessment at building level is based on the Life Cycle Costing (LCC) methodology as developed in the standards [21], [22], [23], aligned with Level(s).

The LCC methodology is a comprehensive approach used to assess the total cost of owning and operating an asset or a project throughout its entire life cycle. It considers all relevant costs and benefits associated with the asset from its initial conception through construction or acquisition, operation, maintenance, and finally, its disposal or end-of-life.

2.4.3.1 Output data

The output data of this assessment are listed in Table 34.

Table 34. Output data. Finances Component. Operational assessment. Building level

Description	Symbol	Unit	Component of destination
Total output data			
As designed energy cost	EC_d	€/m²/an €/m²/month	-
As operated energy cost	EC_o	€/m²/an €/m²/month	-
Predicted energy cost per *N* years	$EC_{p;N}$	€/m²/N an	-
Payback Period	PBP	Years, months	-
Net Savings	NS		-
Savings-to-Investment Ratio	SIR		-
Output data per service or per energy carrier			
As operated energy cost per service or per energy carrier	$EC_{o;X}$	€/m²/an €/m²/month	-
Predicted energy cost per *N* years, per service or per energy carrier	$EC_{p;X;N}$	€/m²/N an	-

The *as-designed* indicators refer to the asset data of the building, indicating the costs as calculated. The *as-operated* indicators refer to the actual energy consumption of the building. The *predicted* indicators indicate the total costs of energy, in addition to the future costs of maintenance and replacement, for the period of 10 years.

The *as-designed* indicators, in comparison to *as-operated*, can also be useful for the classification system. The LCC approach is used mostly for the *predicted* group of indicators, considering the costs in the lifetime of the component or building and taking different yet related types of costs into account. This approach is also aligned with Level(s) indicator 6.1 LCC.

These three categories of financial indicators provide different financial insight to the user, such as comparison of as-designed and as-performed costs, and comparison of different future strategies regarding energy efficiency and technical systems of the building with as-operated indicators. It can be said that the as-designed indicators provide a possibility of comparison for the as-operated indicators, and as-predicted indicators provide insight for decision making (which is also used in the Nudge-ready Performance Benchmarking & Evaluation Tool). However, only the as-operated indicators will be used for the sake of classification and rating in the operational methodology.

There have been too many indicators in total defined for the operational rating methodology, from which it was decided to select only five per part. Therefore, from the as-operated financial indicators, five indicators have been selected for the final framework of the operational rating methodology, which are as following:

1. Cost of heating per floor area per year
2. Cost of cooling per floor area per year
3. Cost of lighting per floor area per year
4. Cost of domestic hot water per floor area per year
5. Cost of appliances per floor area per year

2.4.3.2 Measurement intervals and measurement period

As indicated in related section for the operational energy performance assessment.

2.4.3.3 Input data

An overview is included in Table 35. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 35. Input data. Finances Component. Operational assessment. Building level

Description	Symbol	Unit	Range	Origin	Varying
Discount rate [a]	n/a	-	0…1	Various, ISO 15686-5	No
Discount rate type	D (nominal discount rate) d (real discount rate)	-	Real…Nominal	Various, ISO 15686-5	No
Inflation rate [a]	I	-	0…1	Various, ISO 15686-5	No
Delivered energy costs	EC_{del}	€/kWh	0…∞	Various [a]	Yes
Maintenance costs	MC		0…∞	Various [a]	Yes
Measured actual Delivered energy [b]	$E_{del;j}$	kWh/m²/month	0…∞	Various, Energy performance	Yes
Delivered energy per service	$E_{del;X;j}$	kWh/m²/month	0…∞	Various, Energy performance	Yes

NOTE *CAR_NAMEj is the name of energy carrier j*
[a] According to Regulation 244/2012, Article 3, "*Member States shall complement the comparative methodology framework by determining for the purpose of the calculations the estimated economic lifecycle of a building and/or building element; the discount rates; the costs for energy carriers, products, systems, maintenance costs, operational costs, and labour costs; the primary energy factors; the energy price developments to be assumed for all energy carriers considering the information in Annex II to this Regulation*"
[b] "Actual" refers to being calculated/measured without applying any corrections such as those for weather or building usage.

According to ISO 15686-5, the type of discount rate, either real or nominal, should be clearly distinguished. If real costs are used in the LCC analysis, assumptions about the general rate of inflation should not be required. However, if nominal costs are used in the LCC analysis, assumptions can be made about discount rates (and underlying inflation rates), but they should be explicit, and the sensitivity should be checked. The nominal cost is the current value without taking inflation into account. The real cost is the nominal value after it has been adjusted for inflation.

ISO 15686-5 also indicates that where analysis is made of energy costs, present-day supply costs should be used unless it is foreseeable that the relative costs can change between alternative energy sources. Where an investment appraisal assesses energy-efficient technology, energy savings should be treated as a future income stream (or negative cost) for comparison purposes.

2.4.3.4 Measurement procedure

As indicated in section 2.4.2 for the operational energy performance assessment.

2.4.3.5 Calculation of the financial performance

For calculating the five selected financial indicators in the framework of operational rating methodology, the following steps should be taken:

1. The measured energy, as an input, is measured, as described in related section.
2. The energy costs per carrier and use for the same measured period are collected. This amount can be provided by the energy bills (smart meters).
3. The LCC calculation model is set by the selected financial indicators (according to national Cost Optimal reports) or the preferences of the user.
4. The calculation of the LCC is based on ISO 15686-5.

2.4.3.6 Reporting

The main performance indicator for the financial component of SmartLivingEPC operational assessment is the energy costs as operated. As there are no European standardized or widely accepted benchmarks, a rating has not been defined at the methodological level for this component.

2.4.4 Indoor Environmental Quality

The indoor environmental quality (IEQ) dimension of the SmartLivingEPC operational assessment for buildings or building units is rooted in the Level(s)[4] framework. Level(s) is a European framework for sustainable buildings, providing IEQ indicators in User Manual 3, under Macro-Objective 4: Healthy and comfortable spaces, where the indicators 4.1 to 4.4 can be found for indoor air quality (IAQ), thermal comfort, lighting and visual comfort, and acoustics.

Regarding numeric values, Level(s) indicators 4.1: IAQ and 4.2: Thermal Comfort refer to EN 16798-1:2019 standard [5], which uses Categories I to IV to describe IEQ level. Virus risk is currently not addressed in Level(s) nor in EN 16798-1:2019, but it fits into the IAQ scope specified in these documents. For lighting and visual comfort

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

in buildings, Level(s) 4.3 refers to EN 17037:2018, specifying parameters that are categorized as Minimum, Medium, and High. Lastly, Leve(s)' indicator 4.4 is focused on acoustics and protection against noise. When aiming at a healthy indoor climate, it is proposed to use the normal level of Category II specified in EN 16798-1:2019, whose values will not only ensure avoiding adverse health effects but will also improve the comfort and well-being of occupants.

Indoor air quality and thermal comfort depend on parameters that may be continuously controlled with building technical HVAC systems; therefore, it is important to define acceptable ranges and deviations to enable performance verification. Acoustics' parameters may be verified by discontinuous measurements typically conducted in the commissioning phase. The same applies to artificial lighting; however, in operation, energy-efficient lighting is controlled based on daylight and occupancy. Daylight requirements are mostly verified during the design phase by geometry, window types, orientation, and shading. Some of the parameters are in practice, difficult to measure as they require specific sky conditions and sun angles. This enables to set of minimum requirements for acoustics and lighting parameters, for which some guidance is provided in EN 16798-1:2019 and EN 17037:2018. For these reasons, the SLE operational IEQ assessment focusses on assessing thermal comfort and IAQ indicators.

2.4.4.1 Zoning

Measuring indoor environment quality parameters in every room of a building might seem ideal for a comprehensive assessment, but several practical considerations make it impractical to deploy sensors everywhere. The cost of sensors, the time required for planning and data analysis, and logistical challenges are significant factors that limit the feasibility of such widespread deployment. Therefore, a strategic approach is essential to optimize resource allocation and prioritize rooms for IEQ measurements.

The primary obstacle to installing sensors in every room is the cost. IEQ sensors can be expensive, and the expense multiplies with the number of rooms in a building. For large buildings with numerous spaces, deploying sensors everywhere can become financially prohibitive. Budget constraints often necessitate a more targeted strategy that balances cost-effectiveness with the need for accurate IEQ data.

Time is another crucial factor. Installing sensors throughout a building requires extensive planning and coordination, including site visits, sensor placement, and data logging setup. As the number of rooms increases, the logistical complexity escalates, and analysing the collected data demands significant time and computational resources. Focusing on representative rooms streamlines the process, allowing for efficient data collection and analysis while still providing valuable insights into IEQ conditions.

Additionally, maintaining and managing a large-scale sensor network presents practical challenges. Regular maintenance, calibration, and troubleshooting of numerous sensors can be time-consuming and resource intensive. The logistics become even more complicated when sensors need periodic replacement or servicing, especially when spread across a vast building. By prioritizing certain rooms for sensor deployment, the complexity of maintenance is reduced, ensuring the long-term sustainability of the IEQ measurement system.

Given these challenges, a more strategic and targeted approach is necessary to achieve a meaningful assessment of IEQ in buildings. By carefully selecting rooms for sensor deployment based on factors such as occupancy, room typology, and other relevant criteria, a representative sample can be obtained that captures the variability of IEQ conditions. This approach optimizes resources in terms of both cost and time while still delivering valuable insights into the building's overall indoor air quality profile.

When selecting a limited number of rooms for IEQ measurements in buildings where installing sensors in every room is not feasible, several criteria can be considered to ensure a representative sample, such as those described by Wargocki et al. [24]. These criteria include, but are not limited to:

- **Occupied Rooms**: To ensure the assessment reflects real-life IEQ conditions, prioritize selecting rooms that are actively occupied. Occupancy can affect indoor pollutant generation and ventilation rates, thus influencing IEQ parameters.
- **Occupation Density**: It is important to select rooms with the lowest and highest occupation density. This allows for an assessment of IEQ conditions under varying occupancy levels, which can significantly influence air quality.

- **Geographic Orientations**: Rooms with different geographic orientations should be chosen. This ensures that IEQ measurements capture potential variations in sunlight exposure, airflow patterns, and outdoor pollutant infiltration, which can differ depending on a room's orientation.
- **Street/Road and Garden-Facing Rooms**: Selecting rooms facing different environments, such as streets, roads, and gardens, helps evaluate the impact of outdoor pollution sources and vegetation on IEQ. These different settings can introduce diverse pollutant profiles and airflow characteristics.
- **Typologies of Rooms**: It is important to include rooms with different typologies, which may include:
    - Rooms built or retrofitted during the same period: This accounts for potential differences in building materials, ventilation systems, and overall IEQ performance based on construction practices during specific periods.
    - Rooms sharing the same air handling unit and ventilation/air conditioning zone: This allows for assessing IEQ similarities and differences within the same controlled environment.
    - Rooms with similar building materials and furniture: Similar materials and furniture can affect IEQ through emissions of volatile organic compounds (VOCs) and other pollutants.
    - Rooms with similar types of solar shading devices: Solar shading devices can impact thermal conditions and air circulation, which can influence IEQ.
    - Specific Room Types: Buildings with office spaces, including both single and open-plan offices, allow for evaluating IEQ in different work environments. In hotels or similar establishments, selecting rooms of various sizes provides insights into IEQ variations across different guest accommodations.

By considering these room selection criteria, the IEQ measurements will provide a representative overview of the building's indoor environment, accounting for numerous factors that contribute to air quality variations.

2.4.4.2 Input data

The IEQ operational assessment requires general input data at both the building and room(s) level. An overview is included in Table 36. General information such as the number of floors and the identification of the zones to be assessed (e.g., rooms ID in non-residential buildings) should also be provided. In addition, information gathered in the Overarching preparation steps is also relevant.

Each sub assessment describes specific input data that should be gathered.

Table 36. Input data. IEQ component. General input. Operational assessment. Building level.

Name	Symbol	Unit	Range	Origin*	Varying
Useful floor area, per zone *z*	A_z	m^2	0…∞	Various	No
Volume, per zone *z*	V_z	m^3	0…∞	Various	No
Space category, per zone *z*[a]		LIST		Various, M1-1	No
Occupancy, per zone *z*[a,b]		-	0-1	Various, M1-6	Yes
Occupancy days, per building		-	1-7	Various	No

* When a module is listed, it is referred to the codification of the EPB Standards.

[a] When the information can't be obtained at zone level, building level parameters may be used.

[b] Covering the same period as the sub-assessment measurements.

One critical aspect in assessing IEQ is occupancy detection, as it significantly influences the overall evaluation. While standardized building use and occupancy profiles are commonly used for energy efficiency assessments, they may not accurately reflect the actual room utilization and occupancy patterns. Therefore, relying solely on such profiles can lead to misleading results in IEQ assessments. It is important to account for variations in room utilization during different times of the day or week.

There are multiple solutions to measure or estimate the number of people in room. However, they are diverse regarding accuracy, so a hierarchy exists. The first option is using occupancy counter that gives the number of people in room in specific time (measured). Alternatively, meeting attendees counted (e.g. people who accepted the physical meeting request in room) (measured). Also, it is possible to use CO_2 measurements, standard CO_2 emission per people in specific room and measured (or if Constant Air Volume ventilation systems, then designed) air flow to the room when people are in room. (calculated/estimated). As last options, using general people density from standard in specific room (estimated from standard) or indirectly counting occupants (e.g. chairs in classroom) (estimated).

2.4.4.3 Measurement equipment specifications

Operational indoor air quality (IEQ) measurements involve the assessment of various physical quantities to ensure a satisfactory indoor environment. The data measurement and logging interval is set at 15 minutes, which is considered optimal for balancing data density, analysis, and post-processing, while still providing valuable information compared to shorter logging intervals.

To streamline the measurement process, it is recommended to use a single Internet of Things (IoT) device that can measure multiple parameters simultaneously. This approach simplifies data collection and reduces the number of devices required. For example, an IoT device with capabilities to measure air temperature, relative humidity, CO_2 concentration, and fine particulate matter (PM2,5) would be ideal for capturing key indicators of indoor air quality.

In the requirements proposed by SmartLivingEPC for the measurement equipment used are listed in Table 37.

Table 37. Measurement equipment specifications. IEQ component. Operational assessment. Building level.

Measured item	Unit	Logging interval	Nwetwork protocol
Room air temperature	°C	15 minutes	Modbus/LoRA etc.
Room air relative humidity	%	15 minutes	Modbus/LoRA etc.
Room air CO_2 volumetric concentration	ppm	15 minutes	Modbus/LoRA etc.
Room air PM2,5	µg/m3	15 minutes	Modbus/LoRA etc.
Outdoor air temperature	°C	15 minutes	Modbus/LoRA etc.
Outdoor air relative humidity	%	15 minutes	Modbus/LoRA etc.
Outdoor air CO_2 volumetric concentration	ppm	15 minutes	Modbus/LoRA etc.
Outdoor air PM2,5	µg/m3	15 minutes	Modbus/LoRA etc.
Ventilation volumetric air flow rate	L/s	15 minutes	Modbus/LoRA etc.
Room occupancy (presence sensor)	Binary	15 minutes	Modbus/LoRA etc.
Number of occupants	person	15 minutes	Modbus/LoRA etc.
Occupant feedback questionnaire	Categoric scale	When prompted/on user demand	Modbus/LoRA etc.

2.4.4.4 Measurement intervals and measurement period

The measurement interval is the time between readings of sensors. SmartLivingEPC operational IEQ assessment defines a targeted sampling frequency of 15-minute, with a maximum allowed frequency of 1 hour.

The measurement period is the interval of time covered by measurement intervals. To average out the effect of climate and/or user behaviour, the required measurement period may be a multiple of the assessment period. SmartLivingEPC operational IEQ assessment defines at least a 1-week measurement period, but it could be more extensive (e.g., monthly, season, year).

Validation criteria specify the required number of measurement intervals and the minimum required duration of the measurement period. There should be at least one week 1-hour datapoints within occupancy hours to assess the IEQ components. There could be maximum 40% datapoints missing during the occupancy hours in the assessment period.

Regarding the assessment period, SmartLivingEPC performs the calculation over a year by default.

For the virus risk, the assessment frequency can be diverse depending on the specifics of the object. SmartLivingEPC indicates the following:

a. Single calculation, at the beginning of the monitoring, when the number of people and air flow are constant (default values or assumed),
b. Once a month, when there is no mechanical ventilation, but the number of people is changing (not constant). Therefore, the air flow should be calculated from the average air change rate over the month during occupancy time.
c. Every hour or sub-hourly, when there is Constant Air Volume ventilation, and the number of people is changing (not constant) over the month.
d. Every hour or sub-hourly, when there is Demand Controlled Ventilation.

2.4.4.5 General data validation

Previous studies have shown that raw sensor data, if not pre-treated correctly, has little value due to numerous, rather frequently occurring physical and digital disturbances. Therefore, it is critically important to:

1. Validate that the correct type of data is logged with the correct tag (e.g., temperature, CO_2).
2. Remove outliers and anomalous behaviour (in practice, that can happen often) to a statistically satisfactory extent.
3. As per signal type, apply appropriate data correction algorithms for known types of disturbances (such as the CO_2 baseline shifting problem). The presence of additional data streams (e.g., outdoor CO_2level, room temperature, etc.) can be beneficial to assist the detection and correction of certain anomalies via advanced algorithms.

Measured data often have gaps. This came out also in case studies, that the missing data period varies from 1 hour to 1 month. "If data are measured using an automated weather station (AWS), the most frequent causes of data gaps are related to data transfer, data logging and/or sensor malfunctioning, exceptional equipment maintenance, or the removal of erroneous or unreasonable recorded data.” [25].

There are multiple methods for data gaps filling based on statistical techniques that use historical data and objective analysis for the spatial interpolation of data. Furthermore, Machine Learning technologies are good performing in the matter of indoor temperature prediction as they handle the non-linearity of data.
However, there must be critical with choosing the methodology for temperature data validation.

In this methodology, there is no data filling, but the weekly, monthly, or annual calculation should not be done if there is only 60% or less data available in this period. Furthermore, this methodology do not include data processing and outliers’ detection. Therefore, the final IEQ assessment will include outliers due to sensor anomalies.

2.4.4.6 Thermal Comfort

2.4.4.6.1 Output data

The main indicator to evaluate the thermal comfort is the time spent in each thermal comfort category per assessed zone within occupancy hours, as described in Table 38.

Table 38. Output data. IEQ component. Thermal Comfort. Operational assessment. Building level.

Description	Symbol	Unit	Component of destination
Time spent in each Category, for thermal comfort, per zone z		h	-
		% of total occupancy	
The percentage of time when temperature exceeds category limit for 1°C, for thermal comfort, per zone		% of total	
The percentage of time when temperature exceeds category limit for 2°C, for thermal comfort, per zone		% of total	

The numeric indicators above do not yet automatically reveal the thermal quality of the assessed zone with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end the thermal comfort category obtained following the TAIL rating methodology [24], which is described in section 2.4.4.6.4.

For each room the score will be selected from the Category-Score table (Table 39), based on the calculated category. The total score for thermal comfort will be calculated as the arithmetic mean of the rooms' IEQ scores, only including rooms where the indicator was measured, and a score was assigned. For visualization, the Total Category will be determined based on the Category-Score table (Table 39).

Table 39. The Category-Score table for the IEQ assessment method

Category	Score
A	100
B	87.5
C	75
D	62.5
E	50
F	37.5
G	25
OUTSIDE	0

2.4.4.6.2 Input data

The input data listed in Table 40 is needed per zone. General information such as the occupancy time, number of floors and the identification of the zones to be assessed (e.g., rooms ID in non-residential buildings) should also be provided. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 40. Input data. IEQ component. Thermal Comfort. Operational assessment. Building level.

Name	Symbol	Unit	Range	Origin*	Varying
Metabolic rate	M	met		Various, M1-6	Yes

Space category, per zone z^a		-	LIST	Various, M1-1	No
Occupancy, per zone $z^{a,b}$		-	0-1	Various, M1-6	Yes
Measured **dry-bulb room temperature**, per zone z		°C	10…40	Measurements	Yes
Measured **outdoor air temperature**[c]		°C	-15…50	Measurements, M1-3	Yes
* When a module is listed, it is referred to the codification of the EPB Standards. [a] When the information can't be obtained at zone level, building level parameters may be used. [b] Covering the same period as the dry-bulb room temperature measurement. [c] The maximum allowed timestep is daily average.					

The zone temperature should be collected after a minimum occupancy time and shall be recorded for the measurement period.

The indoor air temperature ranges for thermal comfort categories reproduced in Table 41 can be used for the purpose of methodological demonstration, in absence of EU-wide standardised or recognised alternatives.

Table 41. Indoor air temperature ranges for thermal comfort categories. Adapted from EN 16798-1

Category	**Residential buildings** (1,2 met)		**Residential buildings** (1,5 met)		**Residential buildings** (1,2 met)	
	Temperature range for heating [°C]. Clothing approx. 1,0 clo	Temperature range for cooling [°C]. Clothing approx. 0,5 clo	Temperature range for heating [°C]. Clothing approx. 1,0 clo	Temperature range for cooling [°C]. Clothing approx. 0,5 clo	Temperature range for heating [°C]. Clothing approx. 1,0 clo	Temperature range for cooling [°C]. Clothing approx. 0,5 clo
A	21,0…25,0	23,5…25,5	18,0…25,0	-	21,0…23,0	23,5…25,5
B	20,5…25,0	23,3…25,75	17,0…25,0	-	20,5…23,5	23,3…25,75
C	20,0…25,0	23,0…26,0	16,0…25,0	-	20,0…24,0	23,0…26,0
D	19,0…25,0	22,5…26,5	15,0…25,0	-	19,5…24,5	22,5…26,5
E	18,0…25,0	22,0…27,0	14,0…25,0	-	19,0…25,0	22,0…27,0
F	17,5…25,00	21,5…27,5	-	-	18,0…25,0	21,5…27,5
G	17,0…25,0	21,0…28,0	-	-	17,0…25,0	21,0…28,0
n/a	Out of the above ranges					

2.4.4.6.3 Assessment procedure

1. Calculate the outdoor running mean temperature for the considered day based on the daily average value of the measured data, according to EN 16798-1:2019's formula B.1.
2. Definition for the building category or, if differentiated, for each space category, of the category limits indicated in EN 16798-1:2019's. To that end, in residential buildings the activity level shall also be considered. The following logic shall be followed:

- If the running mean outdoor temperature is below 10°C, then the applicable temperature range is that of the heating season.
- If the running mean outdoor temperature is between 10°C and 15°C, then choose the temperature upper and lower limits that lie between heating and cooling season.
- If the running mean outdoor temperature is over 15°C, then choose the temperature range for cooling season.

3. Using the indoor temperature measurements inside the occupancy time, calculate the number of hours spent within the respective class boundaries for each zone.
4. Calculate the percentage of time when temperature exceeds category limit for 1°C and percentage of time when temperature exceeds category limit for 2°C.
5. Choose the category where the percentages will meet the TAIL 5/1% rule (see description in Reporting below)

2.4.4.6.4 Reporting

The main performance indicator for the thermal comfort component of SmartLivingEPC operational assessment is the thermal comfort category calculated as defined in TAIL [24].

The method is to calculate the percentage (%) of time that is spent within each thermal comfort category according to the temperature limits (Table 41). The TAIL methodology [24] considers that "the temperatures can exceed the indicated range by 1 °C for no more than 5%, and by 2 °C for no more than 1% of the occupancy time during which the measurements were performed (during the working hours in offices and night-time sleeping hours in hotels)." The SmartLivingEPC methodology: 1) Calculate first the hours that the indoor temperatures are 1°C and 2°C over each category limits 2) Calculate the percentages over total hours. 3) Finally, using the 5/1% rule (respectively for 1°C and 2°C), choose the category of room thermal comfort.

2.4.4.7 Indoor Air Quality

When measuring indoor air quality (IAQ), selecting the most appropriate variables to monitor is essential for obtaining a comprehensive understanding of the indoor environment. While there are numerous pollutants and variables present in indoor air, such as radon, volatile organic compounds (VOCs), and formaldehyde, specific choices must be made regarding which parameters to include in the measurement protocol. In this context, carbon dioxide (CO_2) and fine particulate matter (PM2,5) have been chosen as indicative variables due to their significance in assessing IAQ and their practical considerations, while other variables were omitted.

Carbon dioxide is a widely recognized indicator of indoor air quality, primarily because it is directly related to human occupancy and ventilation. As humans exhale CO_2, its concentration increases in poorly ventilated spaces, potentially leading to discomfort, drowsiness, and decreased cognitive function. Monitoring CO_2 levels provides insights into the effectiveness of ventilation systems and the adequacy of fresh air supply. Furthermore, high CO_2 concentrations can indicate the presence of other indoor pollutants, as insufficient ventilation can result in the accumulation of various contaminants. CO_2 is also a relatively easy parameter to measure, with cost-effective sensors readily available in the market.

Fine particulate matter refers to tiny airborne particles with a diameter of 2,5 micrometres or less. These particles can be generated from various sources, including combustion processes, cooking, smoking, and outdoor pollutants that infiltrate indoor spaces. PM2,5 is of particular concern due to its ability to penetrate deep into the respiratory system, potentially causing adverse health effects. Monitoring PM2,5 levels allow for an assessment of the level of particulate pollution and can help identify sources of indoor particle emissions. Like CO_2, PM2,5 measurements are accessible through commercially available sensors, making them a practical choice for IAQ assessment.

The operational rating assessment for indoor air quality within the SmartLivingEPC framework follows the guidelines outlined in EN 16798-1:2019, which provides criteria for assessing indoor air quality and ventilation rates. Specifically, Method 1 of the standard is employed, which determines design ventilation rates based on perceived air quality, considering both the occupant density, and building materials used.

2.4.4.7.1 Output data

The main indicator to evaluate the IAQ comfort is the time spent in each IAQ category per assessed zone, as described in Table 42.

Table 42. Output data. IEQ component. IAQ. Operational assessment. Building level.

Description	Symbol	Unit	Component of destination
Time spent in each Category, for CO_2		h	-
		% of total occupancy	
Time spent in each Category, for PM2,5		h	-
		% of total occupancy	

The numeric indicators above do not yet automatically reveal the IAQ of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, the IAQ comfort category obtained following the TAIL rating methodology [24] is used. The rating process is described in section 2.4.4.7.4.

For each room the score will be selected from the Category-Score table (Table 39), based on the calculated category. The total score for IAQ CO_2 and PM2,5 component will be calculated as the arithmetic mean of the rooms' IEQ scores for that specific component, only including rooms where the indicator was measured, and a score was assigned. For visualization, the Total Category for each component will be determined based on the Category-Score table (Table 39).

2.4.4.7.2 Input data

The input data listed in Table 43 is needed per zone. General information such as occupancy time, the number of floors and the identification of the zones to be assessed (e.g., rooms ID in non-residential buildings) should also be provided. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 43. Input data. IEQ component. IAQ. Asset assessment. Building level.

Name	Symbol	Unit	Range	Origin*	Varying
Ventilation type, per zone *z*		LIST	CAV, DCV, Natural ventilation	Various, M5-5, M5-6, M5-8	No
Measured **indoor CO_2 volumetric concentration**, per zone *z*		ppm	0…∞	Measurements	Yes
Measured **outdoor CO_2 volumetric concentration**		ppm	0…∞	Measurements	Yes
Emission of pollutants intensity per zone $z^{a,b}$		-	Very low polluting, low polluting, non-low polluting	Input by assessor	No
Level of adaption		-	Adapted, non-adapted	Input by assessor	No
Measured **PM2,5 concentration**, per zone *z*		$\mu g/m^3$	0…∞	Measurements	Yes

Name	Symbol	Unit	Range	Origin*	Varying
Occupancy, per zone z[c]		-	0-1	Various, M1-6	Yes

* When a module is listed, it is referred to the codification of the EPB Standards.

[a] When the information can't be obtained at zone level, building level parameters may be used.

[b] Considering the use of low-emitting materials and intensity of activities implying emission of pollutants

[c] Covering the same period as the indoor CO_2 and PM2,5 measurement.

The zone CO_2 and PM2,5 should be collected after a minimum occupancy time and shall be recorded for the measurement period.

The ventilation rate requirements, for the occupant and material components, reproduced in Table 44 and Table 45 respectively, shall be used for the CO_2 dimension of the IAQ assessment. Also, the CO_2 generation per space category, as indicated in Table 46.

The PM2,5 category limits, reproduced in should be used for the PM2,5 dimension of the IAQ assessment.

Table 44. Ventilation rate requirements, occupant component. Adapted from EN 16798-1

Category	Ventilation rate requirements [l/(s·pers.)]	
	Non-adapted	Adapted
A	10,0	3,50
B	8,5	3,0
C	7,0	2,5
D	5,5	2,0
E	4,0	1,5
F	3,25	1,25
G	2,5	1,00

Table 45. Ventilation rate requirements, material component. Adapted from EN 16798-1

Category	Ventilation rate requirements according to material type [l/(s·m²)]		
	Very low polluting	Low polluting	Non low polluting
A	0,50	1,00	2,00
B	0,43	0,85	1,70
C	0,35	0,70	1,40
D	0,28	0,55	1,10
E	0,20	0,40	0,80
F	0,18	0,35	0,70
G	0,15	0,30	0,60

Table 46. Default CO2 generation per space category. Adapted from EN 16798-1

	Building category				
	Office	Classroom	Meeting room	Bedroom	Living room
CO2 generation [l/h]	20	18	20	13,6	20
Activity [met]	1,2	1,2	1,2	0,8	1,2

Table 47. PM2,5 annual mean category limit values. Adapted from WHO guidelines

Category	Limit concentration [µg/m³]
A	5,00
B	7,5
C	10
D	12,5
E	15
F	20
G	25

OUTSIDE LIMITS	>25

2.4.4.7.3 Assessment procedure

For the CO_2 dimension:

1. Definition for the building category or, if differentiated, for each space category, of the CO_2 generation (q_{CO_2}). The activity level for CO_2 generation shall also be considered.
2. Based on the input by the assessor, determine the ventilation rate requirement per occupant ($q_{occ.}$) and according to the material type ($q_{mat.}$) per ventilation requirement category (i).
3. Considering the outdoor CO_2 volumetric concentration ($[CO_2]_{outdoor}$). Calculate the air quality category limits by solving the room CO_2 mass balance according to outdoor CO_2 concentration, CO_2 generation in the zone, and fresh air exchange rates as per:

$$limit_{CO_2;i} = \frac{q_{CO_2}}{3.6 \cdot (q_{occ.;i} + n_{occ.} \cdot q_{mat;i})} \cdot 1000 + [CO_2]_{outdoor}$$ **Equation 15**

4. Using the indoor CO_2 volumetric concentration measurements inside occupancy time, calculate the number of hours spent within the respective class boundaries for each zone.
5. Calculate the percentage of time within each category
6. Choose the category where the percentages will meet the TAIL 5/1% rule (see description in Reporting below)

For the obtention of the PM2,5 indicators:

1. Definition for the building category or, if differentiated, for each space category, of the limit PM2,5 concentration per each annual mean category (i).
2. Using the indoor PM2,5 volumetric concentration measurements inside the occupancy time, calculate the number of hours spent within the respective class boundaries for each zone.
3. Calculate the percentage of time within each category
4. Choose the category where the percentages will meet the TAIL 5/1% rule (see description in Reporting below)

2.4.4.7.4 Reporting

The main performance indicator for the air quality component of SmartLivingEPC scheme is the IAQ score for the assessed object, which is defined by the lower of the two values calculated with the measured CO_2 and PM2,5 levels during occupancy.

The resulting room IAQ Categories will be calculated using TAIL calculation methodology [24]. Specifically, the CO2 measurements cannot exceed the range defined by the indicated category boundaries and the lower category boundaries for more than 5% of the occupied time and the range defined by the next lowest category boundaries 1% of the time. The examples of the category selection are outlined in Table 48 and Table 49. Building IAQ category is calculated as the arithmetic mean of the individual room categories.

Table 48. Example 1 for IAQ CO_2 assessment

Category	A	B	C	D	E	F	G	OUTSIDE
Percentage in category	5%	90%	1%	2%	1%	1%	0%	0%
Percentage of measurements exceeding the category limits	95%	5%	4%	2%	1%	0%	0%	0%
Selected category			C					

Table 49. Example 2 for IAQ PM2,5 assessment

Category	A	B	C	D	E	F	G	OUTSIDE
Percentage in category	0%	80%	12%	5%	2%	1%	0%	0%

Percentage of measurements exceeding the category limits	100%	29%	8%	3%	1%	0%	0%	0%
Selected category				D				

2.4.4.8 Occupant feedback

The methods described in the previous sections rely on fixed classification criteria for the assessment of IEQ. It is also important to get feedback directly from the room users to cross-check if the calculated IEQ classifications correspond to the actual satisfaction level of the users.

2.4.4.8.1 Output data

The main indicator to evaluate the occupant feedback is the number of respondents in each category for each item per assessed zone and representative occupant group, as described in Table 50.

Table 50. Output data. IEQ component. IAQ. Operational assessment. Building level.

Description	Symbol	Unit	Component of destination
Number of respondents in each Category, for thermal comfort, per zone *z* and respondent group *g*		people	-
		% of total respondents	
Number of respondents in each Category, for IAQ per zone *z* and respondent group *g*		people	-
		% of total respondents	
Number of respondents in each Category, for draught per zone *z* and respondent group *g*		people	-
		% of total respondents	

The numeric indicators above do not yet automatically reveal the performance of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a feedback category is obtained following rating process is described in section 2.4.4.8.5.

The Occupancy Feedback is not included in the building IEQ score. However, if occupancy feedback is collected, it should be presented alongside the Building IEQ score/class. The responses should be gathered from at least 50% of building or zone occupants.

2.4.4.8.2 Assessment methodology

Occupancy feedback focuses on the occupant's subjective assessment of general thermal comfort (also including draught components as a separated sub-indicator) and indoor air quality. This assessment does not include local thermal comfort, such as vertical air temperature difference, range of floor temperature, or radiant temperature asymmetry. The assessment is based on ISO 10551 [26] and ISO 28802[27], which provide a reference evaluation method and post-occupancy surveys of indoor environments and user perceptions of comfort and well-being.

The frequency of the survey should be:

- at least once in 5-year intervals, or
- after the renovation, or
- after the change in HVAC system control, or
- after the change of occupiers or the purpose of the use in a specific building part

According to ISO 10551, "the persons submitted to repeated application of the same judgement scales should be informed beforehand, in order to avoid undesired reactions and to present arguments justifying the application of the procedure."

A comparison of the estimated and actual post-occupancy evaluation of satisfaction/dissatisfaction with the thermal environment is performed using the Predicted Percentage Dissatisfied (PPD), which shall be estimated based on EN ISO 7730:2023 (for mechanically cooled buildings) or the acceptable summer indoor temperature range (for buildings without mechanical cooling).

The output of occupancy feedback is the worst category out of the three components' average category over the total building. Furthermore, the statistical distribution of categories, including all rooms in a building, should be presented. The category limits used for the IAQ, thermal comfort, and draught assessment scale originate from EN 16798-1:2019.

2.4.4.8.3 Input data

The input data listed in Table 51 is to be provided by occupants and needed per zone. General information such as the number of floors and the identification of the zones to be included in the occupant feedback (e.g., rooms ID in non-residential buildings) should also be provided. In addition, information gathered in the Overarching preparation steps is also relevant.

The respondents shall be from representative groups, to be selected by specialists in indoor comfort factors considering the aspects that will influence IAQ. The feedback of each representative group needs to be analysed separately. Possible representative groups are:

- The representative groups of people in the building (tenants, students, teachers, preschool children etc.)
- Occupants in the area with the same HVAC systems (with or without mechanical cooling and ventilation; with or without heating or cooling systems)
- Occupants in rooms with the same building façade (south and north façade feedback should be separated)

Table 51. Input data. IEQ component. Occupant feedback. Operational assessment. Building level.

Name	Range	Origin*	Related measurement[a]
General			
Clothing level by the occupants, now or during the last hour	Descriptive with supporting pictures	Occupant input	-
Activity by the occupants, now or during the last hour	Descriptive with supporting pictures	Occupant input	-
Age of the respondent	0…100	Occupant input	-
Gender of the respondent	Male…Female	Occupant input	-
Indoor Environmental Quality			
General thermal comfort perceived by the respondent, now or during the last hour	Cold, Cool, Comfortable, Warm, Hot	Occupant input	Air temperature, humidity
Air quality perceived by the respondent, now or during the last hour	Not smelly, Slightly smelly, Smelly, Very smelly	Occupant input	CO_2 and PM2,5 volumetric concentrations
Draught perceived by the respondent, now or during the last hour	No draught, Slight draught, Draught, Strong draught	Occupant input	Air temperature, humidity
Identification of specific sources of pollution or discomfort that negatively affect the perception of air	Open answer	Occupant input	-

Name	Range	Origin*	Related measurement[a]
quality and/or thermal comfort now by the respondent			
General satisfaction with air quality and thermal environment by the respondent	Not satisfied, Satisfied	Occupant input	-

[a] These physical measures must be measured and feasible to link with the feedback. For environments where people move around or for large groups of people, ISO 28802:2012 directs that a representative sample of spaces will be required to be measured (for example, in the school gym, there should be multiple measurement points). The air temperature is assumed to be close to the operative temperature.

An example of ways to provide continuous feedback by occupants is shown in Figure 3.

The feedback survey must follow the instructions in standards ISO 10551:2019 and ISO 28802:2012.

The survey must be conducted by specialists in the field of human psychology and indoor comfort factors, who will decide upon the questions to ask about and which aspects to focus on.

The survey must be sent out to all building or room occupants, and there should be a system established to obtain as high a response rate as possible – according to Level(s), at least 30% of the results to be considered representative.

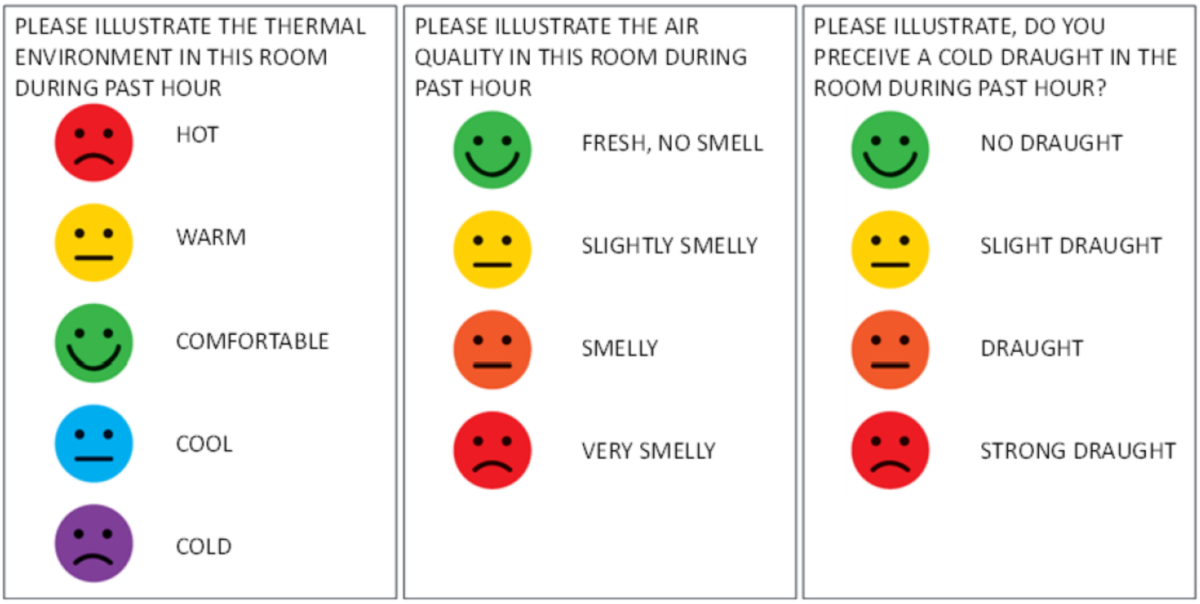


Figure 3. Example of the feedback questions for continuous survey. Source: SmartLivingEPC D3.4

2.4.4.8.4 Assessment procedure

1. Calculate, for each representative group (g) and zone (z) in the building, the number of respondents in each category per input item (i) in absolute and relative terms based on the number of total respondents ($N_{g;z;i}$).
2. Obtain a feedback category following the rating process is described in section 2.4.4.8.5.

2.4.4.8.5 Reporting

The main performance indicators for the occupant feedback are weighted. These are calculated for each input item (i) using the input data from Table 51. Particularly, the number of total respondents ($N_{g;z}$), and the number of respondents in each of the input items. In the end, the mean votes and percentage of dissatisfied calculated for each representative group (g) and zone (z) will be averaged over the building.

For the general thermal comfort, IAQ, draught, through **Equation 16**, **Equation 17**, and **Equation 18**, respectively.

$$WMV_{g;z;TC} = \frac{0 \cdot N_{comf.g;z} + 1.5 \cdot (N_{warm.g;z} + N_{cool.g;z}) + 3 \cdot (N_{hot.g;z} + N_{cold.g;z})}{N_{g;z;i}}$$ **Equation 16**

$$PD_{g;z;IAQ} = \frac{0 \cdot N_{no\ smell.g;z} + 1 \cdot (N_{slightly.g;z} + N_{smelly.g;z} + N_{very\ smelly.g;z})}{N_{g;z;i}}$$ **Equation 17**

$$PD_{g;z;DR} = \frac{0 \cdot N_{no\ draught.g;z} + 1 \cdot (N_{slightly.g;z} + N_{draught.g;z} + N_{strong\ draught.g;z})}{N_{g;z;i}}$$ **Equation 18**

The weighted performance indicators are assigned feedback categories according to the scale depicted in Table 52. The category limits used for the IAQ, thermal comfort, and draught assessment scale originate from EN 16798-1:2019 [5].

Table 52. SmartLivingEPC Occupant feedback performance class. Operational assessment. Building level.

EP Class	Thermal comfort	IAQ	Draught
A	$WMV_{g;z;TC}$ ≤ 0,2	$PD_{g;z;IAQ}$ ≤ 15%	$PD_{g;z;DR}$ ≤ 10%
B	0,2 < $WMV_{g;z;TC}$ ≤ 0,35	15% < $PD_{g;z;IAQ}$ ≤ 17,5%	10% < $PD_{g;z;DR}$ ≤ 13,3%
C	0,35 < $WMV_{g;z;TC}$ ≤ 0,5	17.5% < $PD_{g;z;IAQ}$ ≤ 20%	13,3% < $PD_{g;z;DR}$ ≤ 16,7%
D	0,5 < $WMV_{g;z;TC}$ ≤ 0,6	20% < $PD_{g;z;IAQ}$ ≤ 25%	16,7% < $PD_{g;z;DR}$ ≤ 20%
E	0,6 < $WMV_{g;z;TC}$ ≤ 0,7	25% < $PD_{g;z;IAQ}$ ≤ 30%	20% < $PD_{g;z;DR}$ ≤ 23,3%
F	0,7 < $WMV_{g;z;TC}$ ≤ 0,85	30% < $PD_{g;z;IAQ}$ ≤ 35%	23,3% < $PD_{g;z;DR}$ ≤ 26,7%
G	0.85 < $WMV_{g;z;TC}$ ≤ 1,0	35% < $PD_{g;z;IAQ}$ ≤ 40%	26,7% < $PD_{g;z;DR}$ ≤ 30%
OUTSIDE	$WMV_{g;z;TC}$>1,0	$PD_{g;z;IAQ}$ > 40%	$PD_{g;z;DR}$ > 30%

The output of occupancy feedback is the worst category out of the three components' category over the whole assessed object. Furthermore, the statistical distribution of categories, including all rooms in a building, should be presented.

- The report about the results of the survey must be delivered to the building manager, the building owner, and (preferably) the building occupants as indicated in the manual for Level(s) indicator 4.1. All feedback data should be stored so that each room and complaint can be analysed separately.

2.4.4.9 Virus Risk

In virus risk control, the virus concentration in the air is a central issue because the exposure (=dose) is a product of the breathing rate, concentration, and time. The main engineering measures to control the virus risk are ventilation, air filtration, and disinfection, as shown in Figure 4.

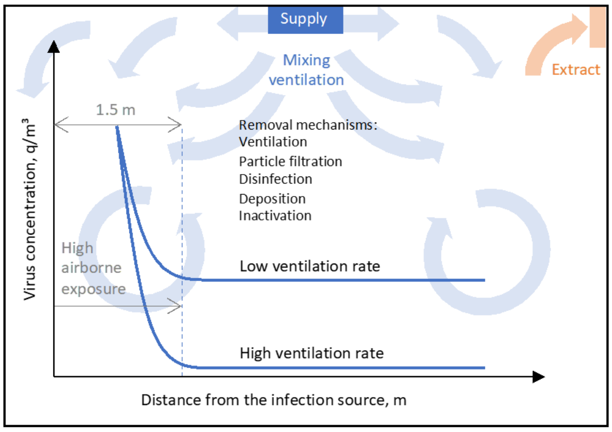


Figure 4. Main removal mechanisms of virus-containing particles [28]

For the concentration control of virus-containing particles, these removal mechanisms can be applied, i.e. viruses can be removed with outdoor air ventilation and filtration or deactivated with UVG. It should be noted that ventilation applies for long-range transmission; therefore, in the case of general ventilation solutions, a physical distance >1.5 m should be applied, meaning that, for instance, in meeting rooms, every second seat needs to be empty.

Virus risk can be calculated from the probability of infection for a susceptible person, for which the infection risk-based ventilation calculation method developed by REHVA [29] can be applied. The virus risk for the rooms with natural ventilation can be calculated only if the outdoor air ventilation rate can be estimated (e.g., from CO_2 measurements using tracer gas concentration decay method).

2.4.4.9.1 Output data

The main indicator to evaluate the virus risk is the reproduction number per assessed zone, as described in Table 53.

Table 53. Output data. IEQ component. Virus Risk. Operational assessment. Building level.

Description	Symbol	Unit	Component of destination
Reproduction number	R	-	-

The numeric indicators above do not yet automatically reveal the risk of virus infection of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, the virus risk category will be selected according to the proposed virus risk estimation scale. The rating process is described in section 2.4.4.9.4.

For each room the score will be selected from the Category-Score table (Table 39), based on the calculated category. The total score for virus risk will be calculated as the arithmetic mean of the rooms' IEQ scores, only including rooms where the indicator was measured, and a score was assigned. For visualization, the Total Category will be determined based on the Category-Score table (Table 39).

2.4.4.9.2 Input data

The input data listed in Table 54 are needed per zone. General information such as the room volume, number of floors and the identification of the zones to be included in the occupant feedback (e.g., rooms ID in non-residential buildings) should also be provided. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 54. Input data. IEQ component. Virus Risk. Operational assessment. Building level

Name	Symbol	Unit	Range	Origin*	Varying
Outdoor air ventilation flow, per zone z^a		m^3/h	0…∞	Measurements	Yes
Number of susceptible persons, per zone $z^{a,b}$	N_s	-	0…∞	Assessor input	Yes

* When a module is listed, it is referred to the codification of the EPB Standards.

[a] When the information can’t be obtained at zone level, building level parameters may be used.

[b] Covering the same period as the sub-assessment measurements.

2.4.4.9.3 Assessment procedure

1. Definition for the space category and volume of the room under assessment
2. Define the outdoor air ventilation flow (measured or defined by user as designed air flow; estimated from CO_2 measurements for natural ventilation) and the number of susceptible people (number of people in room minus one person that is assumed to be infected)
3. Using the room category-specific default values, calculate the event reproduction number for each room
4. Select the category using the proposed virus risk estimation scale based on R values at specified risk levels (Table 53)
5. Provide a calculation report, including the rating as indicated in section 2.4.4.9.4.

2.4.4.9.4 Reporting

The virus risk category will be selected according to the proposed virus risk estimation scale based on R values at specified risk levels (Table 53) for each room. The final building virus risk category should be the worst category within the rooms. As there are no European standardized or widely accepted benchmarks, a rating has not been defined at the methodological level for this component.

2.4.4.10 Calculating the total IEQ score

The total IEQ score for the building will be the lowest (i.e., worst) score among the four components: IAQ-CO_2, IAQ-$PM_{2.5}$, thermal comfort, and virus risk. For example, if the Virus risk has the lowest score, this will be selected as the final IEQ score. If a component score is missing (e.g. the indicator was not measured), it will be excluded from the assessment, with a note indicating which component is missing.

The Occupancy Feedback is not included in the building IEQ score. However, if occupancy feedback is collected, it should be presented alongside the Building IEQ score/class.

Note: The Building IEQ score will be calculated using only the components measured in the building. For example, if PM2.5 measurements are not available in any building rooms, it will be excluded from the assessment, but it should be noted which component(s) are missing from the assessment.

2.5 Asset assessment. Complex level

2.5.1 Output data and Reporting

The output data of this assessment is listed in Table 55.

Table 55. Output data. Asset assessment. Complex level

Description	Symbol	Unit	Component of origin	Component of destination
Street and Public Lighting	SPL	%	Environmental	-
Waste Generation	WG	%	Environmental	-
Waste Recycling Rate	WRr	%	Environmental	-
Wastewater Processing Rate	WwPr	%	Environmental	-
District Heating System	DHS	%	Environmental	-
District Cooling System	DCS	%	Environmental	-
District Heating Potential	DHP	%	Environmental	-
RES ratio	RESr	%	Environmental	-
PV ratio	PVr	%	Environmental	-
STC ratio	STCr	%	Environmental	-
GEO ratio	GEOr	%	Environmental	-
Potential RES ratio	PRESr	%	Environmental	-
PPA and VPPA contracts	PPAc	%	Environmental	-
SMI ratio	SMIr	%	Environmental	-
BEMS ratio	BEMSr	%	Environmental	-
EV Charger Service Rate	EVcR	%	Infrastructure	-
V2G EV Charger Service Ratio	V2GcR	%	Infrastructure	-
EV Charger by building	EVcB	%	Infrastructure	-
Modal Split	MS	%	Infrastructure	-
Fuel Cars Ratio	FCr	%	Infrastructure	-
EV Cars Ratio	EVCr	%	Infrastructure	-
Bike Lanes Ratio	BLr	%	Infrastructure	-
Proximity	Px	%	Infrastructure	-
Shared Mobility	SM	%	Infrastructure	-
Age of the Building Stock	ABS	%	Infrastructure	-
Renovated 30 years old buildings	R30B	%	Infrastructure	-
SmartLivingEPC Asset Energy Performance Rating	SLEPC-E	%	Infrastructure	-
SmartLivingEPC Asset SRI Rating	SLEPC-SRI	%	Infrastructure	-
SmartLivingEPC Asset Sustainability Rating	SLEPC-R	%	Infrastructure	-
SmartLivingEPC Asset Non-Energy Rating	SLEPC-NE	%	Infrastructure	-
Debt Ratio	Dr	%	Social	-
Low Absolute Energy Expenditure	LAEe	%	Social	-
High Share of Energy Expenditure in Income	HSEi	%	Social	-
Thermal Comfort Threshold	TCT	%	Social	-
Heat Island	UHI	%	Social	-
Air Quality	AQI	%	Social	-
Noise	Nz	%	Social	-

2.5.2 Environmental

SmartLivingEPC's environmental component of the asset assessment at the complex level includes three categories: neighbourhood services, renewable energies, and demand side management.

2.5.2.1 Neighbourhood services

2.5.2.1.1 Output data

The output data of this category is listed in Table 56.

Table 56. Output data. Environmental component. Neighbourhood services. Asset assessment. Complex level.

Description	Symbol	Unit	Component of destination
Street and Public Lighting	SPL	%	-
Waste Generation	WG	%	-
Waste Recycling Rate	WRr	%	-
Wastewater Processing Rate	WwPr	%	-
District Heating System	DHS	%	-
District Cooling System	DCS	%	-
District Heating Potential	DHP	%	-

Street and public area lighting refers to the availability of artificial night public lighting, road sign lighting and advertising elements. Lighting not only impacts aspects of energy consumption, but also extends to broader aspects, such as accessibility, the feeling of personal security, road safety and psychological comfort.

Waste generation represents the amount of waste generated per person in the complex area, relative to the national waste generation. Furthermore, the Waste Recycling Rate represents the share of the overall waste generated that is recycled within the complex. Poor performance in terms of waste generation and recycling may correlate with accumulation of garbage in public spaces and residential areas, with subsequent risk of transmission of diseases, pests, exposure to dangerous substances, air, soil and water, mainly affecting populations with fewer resources.

The Wastewater Processing Rate represents the surface coverage of the total complex area by wastewater treatment services.

The District Heating and Cooling System indicator refers to the coverage of such systems in the total complex area. The indicator related to the potential estimates the theoretical coverage that could be provided of thermal uses in the complex area by waste energy generated by industries or factories nearby.

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a class category obtained as described in the related section.

2.5.2.1.2 Calculation intervals and period

The calculation intervals and period are not applicable to the complex-level assessment.

2.5.2.1.3 Input data

The input data listed in in Table 57 is needed per complex. Information of the buildings within the complex (e.g., building category, useful floor area) is required. However, they are assumed to be provided by other modules, particularly those dealing with assessments at the building level.

General information such as the number of buildings and the identification of the buildings within the complex. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 57. Input data. Environmental component. Neighbourhood services. Asset assessment. Complex level.

Name	Symbol	Unit	Range	Origin*	Varying
Illuminated area, within the complex area	IAxc	m^2	0…∞	Various (e.g., municipal observatories, public GIS maps)	No
Total pedestrian area, within the complex area	TPAxc	m^2	0…∞	Various (e.g., municipal observatories, public GIS maps)	No
Waste generation, within the complex area and at national level	WgxcN	Tons	0…∞	Various (e.g., public observatories)	No
Waste recycling, within the complex	Wrxc	Tons	0…∞	Various (e.g., municipal observatories)	No
Total area covered by wastewater treatment services, within the complex	WWTxc	m^2	0…∞	Various (e.g., municipal observatories, public GIS maps)	No
Identification of buildings connected to a district heating	DHBxc	n/a	LIST	Various (e.g., municipal observatories, public GIS maps) and building-level assessment	No
Identification of buildings connected to a district cooling	DCBxc	n/a	LIST	Various (e.g., municipal observatories, public GIS maps) and building-level assessment	No
Identification of nearby industrial waste heat source	IWHs	n/a	LIST	Various (e.g., municipal observatories, public GIS maps)	No

2.5.2.1.4 Calculation procedure

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

For the Street and Public Lighting indicator, the **Illuminated area**, within the complex area, is divided by the **Total pedestrian area**, within the complex area.

For the Waste Generation, the **Waste generation**, within the complex area, is divided by the related value at national level. The Waste Recycling indicator is obtained dividing the amount of recycled waste, within the complex area, by the total waste generation, within the complex area.

The Wastewater Processing Rate indicator is calculated by a ratio of the **Total area covered by wastewater treatment services**, within the complex, covered by the wastewater treatment services and the total complex area.

The **District Heating Potential** is an indicator that applies only when there is available waste heat generated by an industrial source. If such a source exists, the estimation assumes that the available residual energy could meet the thermal needs of an urban area within a 2 km radius from the point of generation.

Provide a calculation report, including the rating as indicated in the following section.

2.5.2.1.5 Reporting

The output indicators are averaged to result in an overall indicator for the category. Then, such an overall indicator is placed in a rating scale as follows:

- The performance scale ranges from Class A to G.

Thus, the category class is assigned to each assessed object based on the equivalence of the building-level.

2.5.2.2 Renewable Energies

2.5.2.2.1 Output data

The output data of this category are listed in Table 58.

Table 58. Output data. Environmental component. Renewable Energies. Asset assessment. Complex level.

Description	Symbol	Unit	Component of destination
RES ratio	RESr	%	-
PV ratio	PVr	%	-
STC ratio	STCr	%	-
GEO ratio	GEOr	%	-
Potential RES ratio	PRESr	%	-

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a class category obtained as described in the related section.

2.5.2.2.2 Calculation intervals and period

The calculation intervals and period are not applicable to the complex-level assessment.

2.5.2.2.3 Input data

The input data listed in in Table 59 is needed per complex. Information of the buildings within the complex (e.g., building category, useful floor area) is required. However, they are assumed to be provided by other modules, particularly those dealing with assessments at the building level.

General information such as the number of buildings and the identification of the buildings within the complex. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 59. Input data. Environmental component. Renewable Energies services. Asset assessment. Complex level.

Name	Symbol	Unit	Range	Origin*	Varying
Identification of buildings equipped with RES	RESBxc	n/a	LIST	Various (e.g., municipal observatories, public GIS maps) and building-level assessment	No
Identification of buildings equipped with photovoltaics	PVBxc	n/a	LIST	Various (e.g., municipal observatories, public GIS maps) and building-level assessment	No
Identification of buildings equipped with solar thermal collectors	STCBxc	n/a	LIST	Various (e.g., municipal observatories, public GIS maps) and building-level assessment	No
Identification of buildings	GSHPBxc	n/a	LIST	Various (e.g., municipal	No

equipped with ground source heat pumps				observatories, public GIS maps) and building-level assessment	
Identification of nearby renewable energy generation	NREG	n/a	LIST	Various (e.g., municipal observatories, public GIS maps)	No

2.5.2.2.4 Calculation procedure

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

For the RES ratio indicator, the **number of buildings equipped with RES**, within the complex area, is divided by the **total buildings**, within the complex area. Similarly for the PV, STC, and GEO ratios, which are focused on a particular renewable generation technology, photovoltaic, solar thermal collectors and ground source heat pumps respectively, rather than renewables in general.

The **Potential RES Ratio** indicator assumes that the potential renewable energy could meet the needs of an urban area within a 2 km radius from the point of generation. Theoretically, buildings to have a connection to the distribution grid would be enough. In any case, there could be complex areas that need special regulations to make possible the connection, in legal terms.

Provide a calculation report, including the rating as indicated in the following section.

2.5.2.2.5 Reporting

The output indicators are averaged to result in an overall indicator for the category. Then, such an overall indicator is placed in a rating scale as follows:

- The performance scale ranges from Class A to G.
- Thus, the category class is assigned to each assessed object based on the equivalence of the building-level.

2.5.2.3 Demand Side Management

2.5.2.3.1 Output data

The output data of this category are listed in Table 60.

Table 60. Output data. Environmental component. Demand Side Management. Asset assessment. Complex level.

Description	Symbol	Unit	Component of destination
PPA and VPPA contracts	PPAc	%	-
SMI ratio	SMIr	%	-
BEMS ratio	BEMSr	%	-

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a class category obtained as described in the related section.

2.5.2.3.2 Calculation intervals and period

The calculation intervals and period are not applicable to the complex-level assessment.

2.5.2.3.3 Input data

The input data listed in in Table 61 is needed per complex. Information of the buildings within the complex (e.g., building category, useful floor area) is required. However, they are assumed to be provided by other modules, particularly those dealing with assessments at the building level.

General information such as the number of buildings and the identification of the buildings within the complex. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 61. Input data. Environmental component. Demand Side Management. Asset assessment. Complex level.

Name	Symbol	Unit	Range	Origin*	Varying
Identification of buildings with a PPA or VPPA contract	PPABxc	n/a	LIST	Various (e.g., surveys, energy communities' databases)	No
Identification of buildings equipped with smart meters	SMBxc	n/a	LIST	Various (e.g., surveys, DSO)	No
Identification of buildings equipped with building energy management systems	BEMSBxc	n/a	LIST	Various (e.g., surveys) and building-level assessment (e.g., operational assessments, related functionalities in SRI component)	No

2.5.2.3.4 Calculation procedure

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

The indicators under this category represent a ratio between the buildings fulfilling certain criteria and the total buildings within the complex area.

Provide a calculation report, including the rating as indicated in the following section.

2.5.2.3.5 Reporting

The output indicators are averaged to result in an overall indicator for the category. Then, such an overall indicator is placed in a rating scale as follows:

- The performance scale ranges from Class A to G.
- Thus, the category class is assigned to each assessed object based on the equivalence of the building-level.

2.5.3 Infrastructure

SmartLivingEPC's infrastructure component of the asset assessment at the complex level includes three categories: EV charger, mobility and transport, and neighbourhood building inventory.

2.5.3.1 EV Charger

2.5.3.1.1 Output data

The output data of this category are listed in Table 62.

Table 62. Output data. Infrastructure component. EV charger. Asset assessment. Complex level.

Description	Symbol	Unit	Component of destination
EV Charger Service Rate	EVcR	%	-
V2G EV Charger Service Ratio	V2GcR	%	-
EV Charger by building	EVcB	%	-

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a class category obtained as described in the related section.

2.5.3.1.2 Calculation intervals and period

The calculation intervals and period are not applicable to the complex-level assessment.

2.5.3.1.3 Input data

The input data listed in in Table 63 is needed per complex. Information of the buildings within the complex (e.g., building category, useful floor area) is required. However, they are assumed to be provided by other modules, particularly those dealing with assessments at the building level.

General information such as the number of buildings and the identification of the buildings within the complex. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 63. Input data. Infrastructure component. EV charger. Asset assessment. Complex level.

Name	Symbol	Unit	Range	Origin*	Varying
Total electric vehicles, within the complex area	TEVxc	cars	0…∞	Various (e.g., municipal observatories, public GIS maps, surveys) and building-level assessment	No
Nominal power of each EV charger, within the complex area	NP-EVcxc	kW	0…∞	Various (e.g., municipal observatories, public GIS maps)	No
Capacity factor of each EV, within the complex area	CF-EVxc	km/kWh	0…∞	Various (e.g., municipal observatories, public GIS maps)	No
Average distance travelled with EV, within the complex area	ADT-EVxc	km	0…∞	Various (e.g., public observatories, surveys)	No
Total V2G electric vehicles,	TV2G-EVxc	cars	0…∞	Various (e.g., municipal observatories,	No

within the complex area				public GIS maps, surveys) and building-level assessment	

2.5.3.1.4 Calculation procedure

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

The **EV charger service Rate** indicator shows, within a complex area, the share of EVs which could be fully charged in a day considering the available EV chargers. Thus, the calculation method is a two-step. First, for each EV charger, the nominal power of the charger, multiplied by 24 hours/day, by the capacity factor. Second, the previous result is divided by the average number of kilometres driven daily.

The **V2G EV Charger Ratio** merely represents the share of all the EV chargers with V2G capabilities within the complex. Similarly to the EV charger by building, which represents the average number of EV chargers per building within the complex.

Lastly, provide a calculation report, including the rating as indicated in the following section.

2.5.3.1.5 Reporting

The output indicators are averaged to result in an overall indicator for the category. Then, such an overall indicator is placed in a rating scale as follows:

- The performance scale ranges from Class A to G.

Thus, the category class is assigned to each assessed object based on the equivalence of the building-level.

2.5.3.2 Mobility and Transport

2.5.3.2.1 Output data

The output data of this category are listed in Table 64.

Table 64. Output data. Infrastructure component. Mobility and Transport. Asset assessment. Complex level.

Description	Symbol	Unit	Component of destination
Modal Split	MS	%	-
Fuel Cars Ratio	FCr	%	-
EV Cars Ratio	EVCr	%	-
Bike Lanes Ratio	BLr	%	-
Proximity	Px	%	-
Shared Mobility	SM	%	-

The proximity indicator refers to the strategic planning and design of urban environments to minimize physical and social distances between essential services, amenities and residential areas.

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a class category obtained as described in the related section.

2.5.3.2.2 Calculation intervals and period

The calculation intervals and periods are not applicable to the complex-level assessment, except for the shared mobility indicator which takes a year as a reference period.

2.5.3.2.3 Input data

The input data listed in Table 65 is needed per complex. Information of the buildings within the complex (e.g., building category, useful floor area) is required. However, they are assumed to be provided by other modules, particularly those dealing with assessments at the building level.

General information such as the number of buildings and the identification of the buildings within the complex. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 65. Input data. Infrastructure component. Mobility and Transport. Asset assessment. Complex level.

Name	Symbol	Unit	Range	Origin*	Varying
Transport mode used and frequency of use by residents, within the complex area	TMFxc	-	LIST	Various (e.g., municipal observatories, surveys)	No
Total fossil fuel vehicles, within the complex area	TFVxc	cars	0…∞	Various (e.g., municipal observatories, public GIS maps, surveys)	No
Total electric vehicles, within the complex area	TEVxc	cars	0…∞	Various (e.g., municipal observatories, public GIS maps, surveys) and building-level assessment	No
Total vehicles, within the complex area	TVxc	km/kWh	0…∞	Various (e.g., municipal observatories, public GIS maps)	No
Bike lane length, within the complex area	BLLxc	km	0…∞	Various (e.g., public observatories, surveys)	No
Road length, within the complex area	RLxc	km	0…∞	Various (e.g., municipal observatories, public GIS maps, surveys) and building-level assessment	No
Number of buildings 500m (or less) away from target buildings, within the complex area	B500xc	Buildings	0…∞	Various (e.g., municipal observatories, public GIS maps, surveys) and building-level assessment	No
Inhabitants having made at least 1 trip with a shared mobility service in the last year,	SM1Yxc	People	0…∞	Various (e.g., surveys)	No

within the complex area					

2.5.3.2.4 Calculation procedure

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

The percentages in the **modal split** table are finally condensed into a single value by a simple operation of adding and subtracting percentages. The final result is a single percentage that reflects "people who do not use a vehicle for their trips."

The indicator **Fuel Cars Ratio** is calculated by determining the total number of private vehicles powered by fossil fuels over the total number of vehicles of the complex area, multiplying by 100. Similarly, the indicator **EV Cars Ratio** is calculated by determining the total number of private vehicles EV powered over the total number of vehicles of the complex area, multiplying by 100."

The **Bike Lane Ratio** represents the division of the total length of bike lanes over the total length of roads within the complex.

The **Proximity Indicator** is calculated dividing the number of buildings at up to 500m of distance from certain target buildings, over the total buildings within the complex area.

The **shared mobility** indicator is obtained by dividing the inhabitants that have used a shared mobility service in the last year over the total amount of inhabitants in the complex area.

Lastly, provide a calculation report, including the rating as indicated in the following section.

2.5.3.2.5 Reporting

The output indicators are averaged to result in an overall indicator for the category. Then, such an overall indicator is placed in a rating scale as follows:

- The performance scale ranges from Class A to G.

Thus, the category class is assigned to each assessed object based on the equivalence of the building-level.

2.5.3.3 Neighborhood Building Inventory

2.5.3.3.1 Output data

The output data of this category are listed in Table 66.

Table 66. Output data. Infrastructure component. Neighborhood Building Inventory. Asset assessment. Complex level.

Description	Symbol	Unit	Component of destination
Age of the Building Stock	ABS	%	-
Renovated 30 years old buildings	R30B	%	-
SmartLivingEPC Asset Energy Performance Rating	SLEPC-E	%	-
SmartLivingEPC Asset SRI Rating	SLEPC-SRI	%	-
SmartLivingEPC Asset Sustainability Rating	SLEPC-R	%	-
SmartLivingEPC Asset Non-Energy Rating	SLEPC-NE	%	-

There are indicators related to the age and renovation of the building stock within the complex area. Also, the representative indicators at the complex-level of the different asset assessments performed in the buildings within.

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a class category obtained as described in the related section.

2.5.3.3.2 Calculation intervals and period

The calculation intervals and period are not applicable to the complex-level assessment.

2.5.3.3.3 Input data

The input data listed in in Table 67 is needed per complex. Information of the buildings within the complex (e.g., building category, useful floor area) is required. However, they are assumed to be provided by other modules, particularly those dealing with assessments at the building level.

General information such as the number of buildings and the identification of the buildings within the complex. In addition, information gathered in the Overarching preparation steps is also relevant.

Table 67. Input data. Infrastructure component. EV charger. Asset assessment. Complex level.

Name	Symbol	Unit	Range	Origin*	Varying
Age of each building, within the complex area	ABxc	years	0…∞	Various (e.g., municipal observatories, public GIS maps, surveys) and building-level assessment	No
Renovation action of each building, within the complex area	RABxc	-	0…1	Various (e.g., municipal observatories, public GIS maps, surveys) and building-level assessment	No
SmartLivingEPC Asset Energy Performance Rating of each building, within the complex area	SLEPC-Exc	%	0…100	Building-level assessment	No
SmartLivingEPC Asset SRI Rating of each building, within the complex area	SLEPC-SRIxc	%	0…100	Building-level assessment	No
SmartLivingEPC Asset Sustainability Rating of each building, within the complex area	SLEPC-Sxc	%	0…100	Building-level assessment	No
SmartLivingEPC Asset IEQ Rating of each building, within the complex area	SLEPC-IEQxc	%	0…100	Building-level assessment	No

2.5.3.3.4 Calculation procedure

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

The **Age of the Building Stock** indicator represents the share of buildings, within a complex area, that are over 30 years old. The **Renovated 30 years old buildings** indicator refers to the share of renovated buildings over 30 years old within the complex area.

The ratings from each component of the **SmartLivingEPC Asset Assessment at the building level** are aggregated over the complex area to result in an equivalent eating at the complex-level.

Lastly, provide a calculation report, including the rating as indicated in the following section.

2.5.3.3.5 Reporting

The output indicators are averaged to result in an overall indicator for the category. Then, such an overall indicator is placed in a rating scale as follows:

- The performance scale ranges from Class A to G.

Thus, the category class is assigned to each assessed object based on the equivalence of the building-level.

2.5.4 Social

SmartLivingEPC's social component of the asset assessment at the complex level includes two categories: energy poverty, and quality of life.

2.5.4.1 Energy Poverty

2.5.4.1.1 Output data

The output data of this category are listed in Table 68.

Table 68. Output data. Social component. Energy poverty. Asset assessment. Complex level.

Description	Symbol	Unit	Component of destination
Debt Ratio	Dr	%	-
Low Absolute Energy Expenditure	LAEe	%	-
High Share of Energy Expenditure in Income	HSEi	%	-
Thermal Comfort Threshold	TCT	%	-

A set of indicators (i.e., debt ratio, low absolute energy expenditure, and high share of energy expenditure in income) focus on the economic aspect of accessing energy, while the thermal comfort threshold assesses the share of households not meeting the minimum comfort requirements.

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a class category obtained as described in the related section.

2.5.4.1.2 Calculation intervals and period

The calculation intervals and period are not applicable to the complex-level assessment.

2.5.4.1.3 Input data

The input data listed in in Table 690 is needed per complex. Information of the buildings within the complex (e.g., building category, useful floor area) is required. However, they are assumed to be provided by other modules, particularly those dealing with assessments at the building level.

General information such as the number of buildings and the identification of the buildings within the complex. In addition, information gathered in the Overarching preparation steps is also relevant.

For this category and component, the number of households within the complex area is also needed.

Table 69. Input data. Social component. Energy poverty. Asset assessment. Complex level.

Name	Symbol	Unit	Range	Origin*	Varying
Arrear in payment of utility bills per household, within the complex area	APUxc	-	0…1	Various (e.g., municipal observatories, public GIS maps, official reports)	No
Annual energy expenditure per household, within the complex area and national median	AEEHxcN	-	€/year	Various (e.g., municipal observatories, public GIS maps, official reports) and building-level assessment	No
Annual Net Income per household, within the complex area and national median	ANIxcN	-	€/year	Various (e.g., municipal observatories, surveys)	No
Hours during occupancy in discomfort per building or building unit, within the complex area	HODxc	%	0…∞	Various (e.g., surveys) and building-level assessment	No

2.5.4.1.4 Calculation procedure

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

The **Debt Ratio** represents the number of households with arrears in the payment of utilities over the total number of households within the complex area. The rest of economic indicators evaluate the energy expenditure. The **Low Absolute Energy Expenditure** assesses the share of homes within the complex area whose energy expenditure is less than half of the national median. The **High Share of Energy Expenditure in Income** represents the share of households whose proportion of energy expenditure in income is more than double the national median over the total households in the complex area.

The **Thermal Comfort Threshold** refers to the share of buildings and building units which do not reach the indoor thermal comfort threshold over the total buildings and building units in the complex area.

Provide a calculation report, including the rating as indicated in the following section.

2.5.4.1.5 Reporting

The output indicators are averaged to result in an overall indicator for the category. Then, such an overall indicator is placed in a rating scale as follows:

- The performance scale ranges from Class A to G.

2.5.4.2 Quality of Life

2.5.4.2.1 Output data

The output data of this category is listed in Table 70.

Table 70. Output data. Social component. Quality of Life. Asset assessment. Complex level.

Description	Symbol	Unit	Component of destination
Heat Island	UHI	%	-
Air Quality	AQI	%	-
Noise	Nz	%	-

The Heat Island Indicator shows the proportion in which the temperature increases locally in certain urban environments, with respect to peripheral areas.

The air quality indicator refers to the condition of the air in and around urban areas, particularly in terms of how clean or polluted it is.

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a class category is obtained as described in the related section.

2.5.4.2.2 Calculation intervals and period

The calculation intervals and period are not applicable to the complex-level assessment.

2.5.4.2.3 Input data

The input data listed in in Table 71 is needed per complex. Information of the buildings within the complex (e.g., building category, useful floor area) is required. However, they are assumed to be provided by other modules, particularly those dealing with assessments at the building level.

General information such as the number of buildings and the identification of the buildings within the complex. In addition, information gathered in the Overarching preparation steps is also relevant.

For this category and component, additional information is needed from public authorities. Particularly, regarding the percentage of population affected by a low air quality index and by high levels of noise.

Table 71. Input data. Social component. Quality of Life. Asset assessment. Complex level.

Name	Symbol	Unit	Range	Origin*	Varying
LST Temperature in the city centre, within the complex	LSTccxc	°C	0…∞	Various (e.g., municipal observatories, public GIS maps)	No
LST Temperature in the peripheral region, within the complex	LSTprxc	°C	0…∞	Various (e.g., municipal observatories, public GIS maps)	No

2.5.4.2.4 Calculation procedure

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

The **Heat Island** is parametrised by means of the Relative Surface Temperature, within the complex, following the method proposed by Xu et al.[30].

Provide a calculation report, including the rating as indicated in the following section.

2.5.4.2.5 Reporting

The output indicators are averaged to result in an overall indicator for the category. Then, such an overall indicator is placed in a rating scale as follows:

- The performance scale ranges from Class A to G.

Thus, the category class is assigned to each assessed object based on the equivalence of the building-level.

2.6 Operational assessment. Complex level

2.6.1 Output data and Reporting

The output data of this assessment are listed in Table 72.

Table 72. Output data. Operational assessment. Complex level

Description	Symbol	Unit	Component of origin	Component of destination
Street and Public Lighting	SPL	%	Environmental	-
Wastewater Treatment Consumption Rate	WTCr	%	Environmental	-
District Energy Systems Heating	DESH	%	Environmental	-
District Energy Systems Cooling	DESC	%	Environmental	-
Renewable energy ratio	REr	%	Environmental	-
Load Demand Factor	LDF	%	Operative	-
EV Charger Electricity Consumption Rate	EVcECr	%	Operative	-
EV Energy Load	EVEL	%	Operative	-
SmartLivingEPC Operational Energy Performance Rating	SLEPC-OE	%	Operative	-
SmartLivingEPC Operational IEQ Rating	SLEPC-OIEQ	%	Operative	-
SmartLivingEPC Operational Financial Rating	SLEPC-OF	%	Operative	-

The numeric indicators above do not yet automatically reveal the quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. Thus, there is a rating used for reporting each component's main output.

In addition, an overall SmartLivingEPC rating is produced based on the following:

- The performance scale ranges from Class A to G.
- For each component included in the assessment, a weighting is given to each component's percentual score. The weightings used shall add up to 100.

Thus, the SmartLivingEPC class is assigned to each assessed object based on the equivalence of Table 73.

Table 73. SmartLivingEPC class. Operational assessment. Complex level.

EP Class	Complex Overall Score
A	≤100
B	≤90
C	≤75
D	≤60
E	≤45
F	≤30
G	≤15

2.6.2 Environmental

SmartLivingEPC's environmental component of the asset assessment at the complex level includes two categories: neighbourhood services, and renewable energies.

2.6.2.1 Neighbourhood services

2.6.2.1.1 Output data

The output data of this category are listed in Table 74.

Table 74. Output data. Environmental component. Neighbourhood services. Operational assessment. Complex level.

Description	Symbol	Unit	Component of destination
Street and Public Lighting	SPL	%	-
Wastewater Treatment Consumption Rate	WTCR	%	-
District Energy Systems Heating	DESH	%	-
District Energy Systems Cooling	DESC	%	-

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a class category obtained as described in the related section.

2.6.2.1.2 Measurement intervals and period

The measurement interval refers to the time between sensor readings. In SmartLivingEPC, the operational evaluation of Neighborhood Services (including environmental indicators such as Street and Public Lighting, Wastewater Treatment Consumption Rate, District Energy Systems Heating, and District Energy Systems Cooling) establishes an objective sampling frequency of 30 minutes, with a maximum allowable frequency of 1 hour during usage hours (which depend on the nature and configuration of each service).

The measurement period represents the time span covered by the measurement intervals. To calculate the average effect of climate conditions or user behavior, the required measurement period may be a multiple of the evaluation period. The SmartLivingEPC operational evaluation of Neighborhood Services defines a minimum measurement period of 1 week.

The validation criteria specify the required number of measurement intervals and the minimum duration of the measurement period. There must be at least one week of hourly data points within the usage hours to evaluate Neighborhood Services. A maximum of 40% of missing data points is allowed during the usage hours within the evaluation period.

Regarding the evaluation period, SmartLivingEPC performs calculations over a one-year period by default.

2.6.2.1.3 Input data

The input data listed in Table 75 is needed per complex. Information of the buildings within the complex (e.g., building category, useful floor area) is required. However, they are assumed to be provided by other modules, particularly those dealing with assessments at the building level.

General information such as the number of buildings and the identification of the buildings within the complex is required. In addition, information gathered in the Overarching preparation steps is also relevant.

In addition, operational energy consumption for complex-level services is required, such as the overall consumption (i.e., per energy carries and weighted energy performance), and the thermal energy needs.

Table 75. Input data. Environmental component. Neighbourhood services. Operational assessment. Complex level.

Name	Symbol	Unit	Range	Origin*	Varying
Street and Public Lighting electricity consumption, within the complex area	SPLECxc	kWh	0…∞	Various (e.g., municipal smart meters)	Yes
Thermal energy needs serviced by efficient heating per building, within the complex area	TNEHxc	kWh	0…∞	Building-level assessment	Yes
Thermal energy needs serviced by efficient cooling per building, within the complex area	TNECxc	kWh	0…∞	Building-level assessment	Yes
Weighted energy performance of Wastewater Treatment Services, within the complex	WEP-WTSxc	kWh	0…∞	Various (e.g., municipal measurements)	Yes

2.6.2.1.4 Measurement procedure

The parameters that are listed in Table 75 are measured by means of standard practice: those of Various origin are to be provided directly by the municipality or by any accessible smart meters, while those that are assessed at the building level are to be retrieved through the electricity use data of the specific building, as per the installed energy meters. Cooling and heating needs are easily distinguished since the heating season is well-defined by each area.

Hourly time steps are customary for aggregation at the district level (i.e., municipality origin), while the installed energy meters in the buildings are constantly delivering data readings with finer time steps.

2.6.2.1.5 Calculation procedure based on measurements

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

Street and public lighting will be addressed at the whole complex level, with cumulative energy use, annually and for each month, for seasonal tracking. **Thermal energy needs** will be aggregated on a yearly basis, to provide a cross-check with the single building EPC (either asset or operational from previous EPCs) and track any evaluation gap. The district building stock's energy performance will then be addressed following the procedure in [31]

Provide a calculation report, including the rating as indicated in the following section.

2.6.2.1.6 Reporting

The output indicators are averaged to result in an overall indicator for the category. Then, such an overall indicator is placed in a rating scale as follows:

- The performance scale ranges from Class A to G.

Thus, the category class is assigned to each assessed object based on the equivalence of Table 73.

2.6.2.2 Renewable Energies

2.6.2.2.1 Output data

The output data of this category are listed in Table 58.

Table 76. Output data. Environmental component. Renewable Energies. Operational assessment. Complex level.

Description	Symbol	Unit	Component of destination
Renewable energy ratio	REr	%	-

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a class category is obtained as described in the related section.

2.6.2.2.2 Measurement intervals and period

The measurement interval refers to the time between sensor readings. In SmartLivingEPC, the operational evaluation of Renewable Energies establishes an objective sampling frequency of 30 minutes, with a maximum allowable frequency of 1 hour during usage hours (which depends on the nature and configuration of each service).

The measurement period represents the time span covered by the measurement intervals. To calculate the average effect of climate conditions or user behavior, the required measurement period may be a multiple of the evaluation period. The SmartLivingEPC operational evaluation of Renewable Energies defines a minimum measurement period of 6 months.

The validation criteria specify the required number of measurement intervals and the minimum duration of the measurement period. There must be at least 6 months of hourly data points within the usage hours to evaluate Renewable Energies. A maximum of 15% of missing data points are allowed during the usage hours within the evaluation period.

Regarding the evaluation period, SmartLivingEPC performs calculations over a one-year period by default

2.6.2.2.3 Input data

The input data listed in in Table 598 is needed per complex. Information of the buildings within the complex (e.g., building category, useful floor area) is required. However, they are assumed to be provided by other modules, particularly those dealing with assessments at the building level.

General information such as the number of buildings and the identification of the buildings within the complex. In addition, information gathered in the Overarching preparation steps is also relevant.

In addition, operational energy consumption for complex-level services is required, such as the overall consumption (i.e., per energy carries and weighted energy performance), and the thermal energy needs.

Table 77. Input data. Environmental component. Renewable Energies services. Operational assessment. Complex level.

Name	Symbol	Unit	Range	Origin*	Varying
Measured on-site electric	MEEPj	kWh	0…∞	Various	Yes

energy produced by sub-system *j*					

2.6.2.2.4 Measurement procedure

Equivalent to 2.6.2.1.4.

2.6.2.2.5 Calculation procedure based on measurements

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

Equivalent to 2.6.2.1.5

Provide a calculation report, including the rating as indicated in the following section.

2.6.2.2.6 Reporting

The output indicators are averaged to result in an overall indicator for the category. Then, such an overall indicator is placed in a rating scale as follows:

- The performance scale ranges from Class A to G.

Thus, the category class is assigned to each assessed object based on the equivalence of Table 73.

2.6.3 Operative

SmartLivingEPC's infrastructure component of the operational assessment at the complex level includes one single category, the neighbourhoods building functioning.

2.6.3.1 Neighborhood Building Functioning

2.6.3.1.1 Output data

The output data of this category are listed inTable 78.

Table 78. Output data. Operative component. Neighbourhood Building Functioning. Operational assessment. Complex level.

Description	Symbol	Unit	Component of destination
Load Demand Factor	LDF	%	-
EV Charger Electricity Consumption Rate	EVcECR	%	-
EV Energy Load	EVEL	%	-
SmartLivingEPC Operational Energy Performance Rating	SLEPC-OE	%	-
SmartLivingEPC Operational IEQ Rating	SLEPC-OIEQ	%	-
SmartLivingEPC Operational Financial Rating	SLEPC-OF	%	-

The numeric indicators above do not yet automatically reveal the energetic quality of the assessed object with respect to a given feature. The indicator needs to be compared to reference values to judge the good or poor performance of the feature under consideration. To that end, a class category obtained as described in the related section.

2.6.3.1.2 Measurement intervals and period

The measurement interval refers to the time between sensor readings. In SmartLivingEPC, the operational evaluation of Neighbourhood Building Functioning establishes an objective sampling frequency of 30 minutes, with a maximum allowable frequency of 1 hour during usage hours (which depends on the nature and configuration of each service).

The measurement period represents the time span covered by the measurement intervals. To calculate the average effect of climate conditions or user behavior, the required measurement period may be a multiple of the evaluation period. The SmartLivingEPC operational evaluation of Neighbourhood Building Functioning defines a minimum measurement period of 6 months.

The validation criteria specify the required number of measurement intervals and the minimum duration of the measurement period. There must be at least 6 months of hourly data points within the usage hours to evaluate Neighbourhood Building Functioning. A maximum of 30% of missing data points are allowed during the usage hours within the evaluation period.

Regarding the evaluation period, SmartLivingEPC performs calculations over a one-year period by default

2.6.3.1.3 Input data

The input data listed in in Table 67 is needed per complex. Information of the buildings within the complex (e.g., building category, useful floor area) is required. However, they are assumed to be provided by other modules, particularly those dealing with assessments at the building level.

General information such as the number of buildings and the identification of the buildings within the complex is required. In addition, information gathered in the Overarching preparation steps is also relevant.

In addition, operational energy consumption for complex-level services is required, such as the overall consumption (i.e., per energy carries and service, and weighted energy performance), and load (i.e., per energy carriers).

Table 79. Input data. Operative component. Neighbourhood Building Functioning. Operational assessment. Complex level.

Name	Symbol	Unit	Range	Origin*	Varying
Peak Electricity Load, within the complex area	PELxc	kW	0…∞	Various	No
Peak EV Electricity Load, within the complex area	PEVLxc	-	0…1	Various	No
SmartLivingEPC Operational Energy Performance Rating of each building, within the complex area	SLEPC-OExc	%	0…100	Building-level assessment	No
SmartLivingEPC Operational IEQ Rating of each building, within the complex area	SLEPC-OIEQxc	%	0…100	Building-level assessment	No
SmartLivingEPC Operational Finances Rating of each building, within the complex area	SLEPC-OFxc	%	0…100	Building-level assessment	No

2.6.3.1.4 Measurement procedure

Equivalent to 2.6.2.1.4.

2.6.3.1.5 Calculation procedure based on measurements

The overall calculation procedure consists of the following calculation steps, to be rolled out after performing the overarching preparation steps, as indicated in section 2.2.2.

Equivalent to 2.6.2.1.5.

Provide a calculation report, including the rating as indicated in the following section.

2.6.3.1.6 Reporting

The output indicators are averaged to result in an overall indicator for the category. Then, such an overall indicator is placed on a rating scale as follows:

- The performance scale ranges from Class A to G.

Thus, the category class is assigned to each assessed object based on the equivalence of Table 73.

3 SmartLivingEPC Web Platform. User Manual

The manual seeks to guide prospective users of the SmartLivingEPC Web Platform on its use, by describing the user interfaces, which are integrated in the platform's architecture, as depicted in Figure 5.

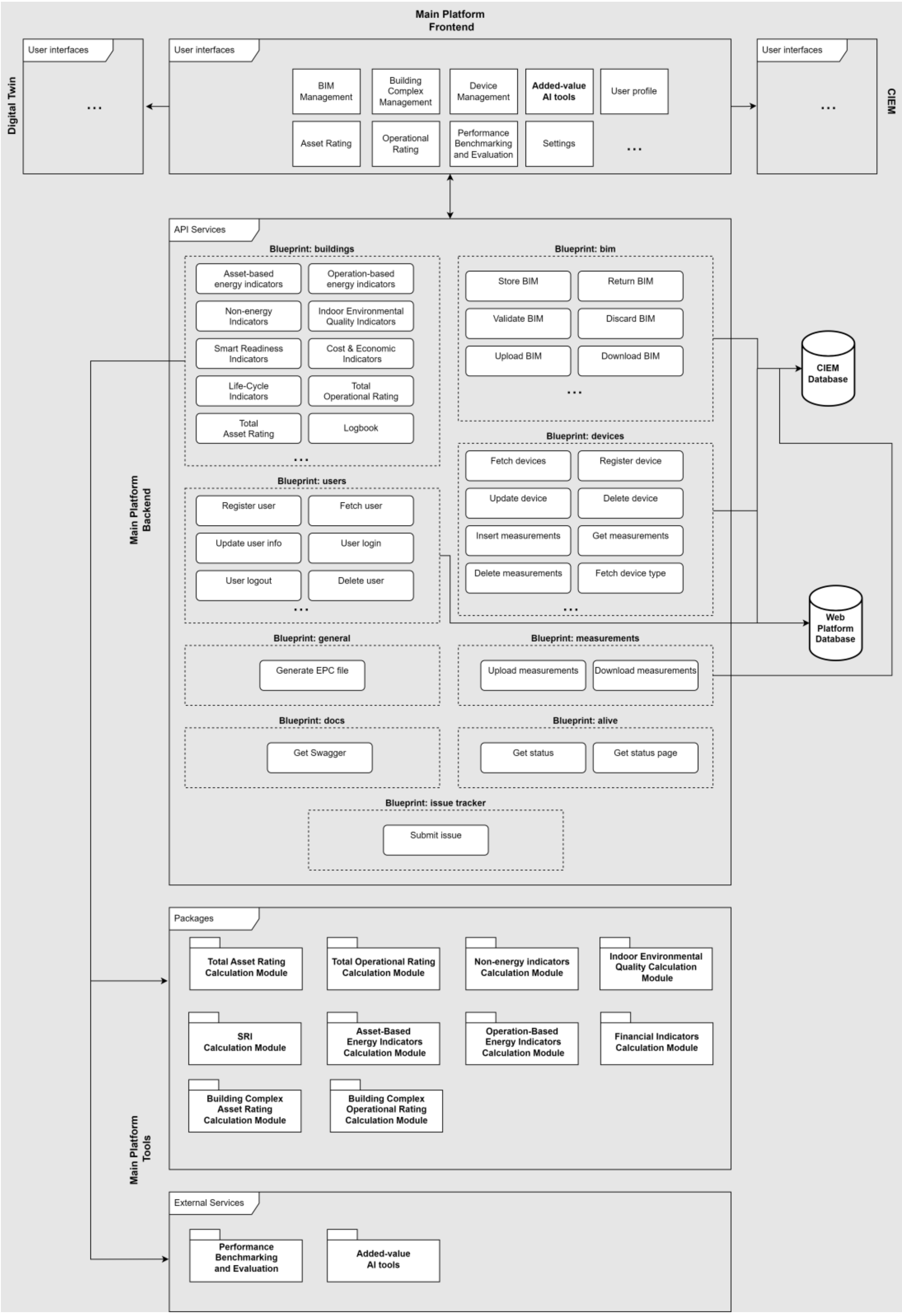


Figure 5. SmartLivingEPC Web Platform Architecture. D5.1

3.1 Getting Started

3.1.1 System Requirements

The SmartLivingEPC Web Platform requires a web browser and an active internet connection to function properly.

3.1.2 Account Creation/Login

The landing page of the platform enables the account creation (Figure 6) and log in (Figure 7). Upon account creation, administrator approval is required. Then, the user receives a confirmation email enabling access into the SmartLivingEPC Web Platform.

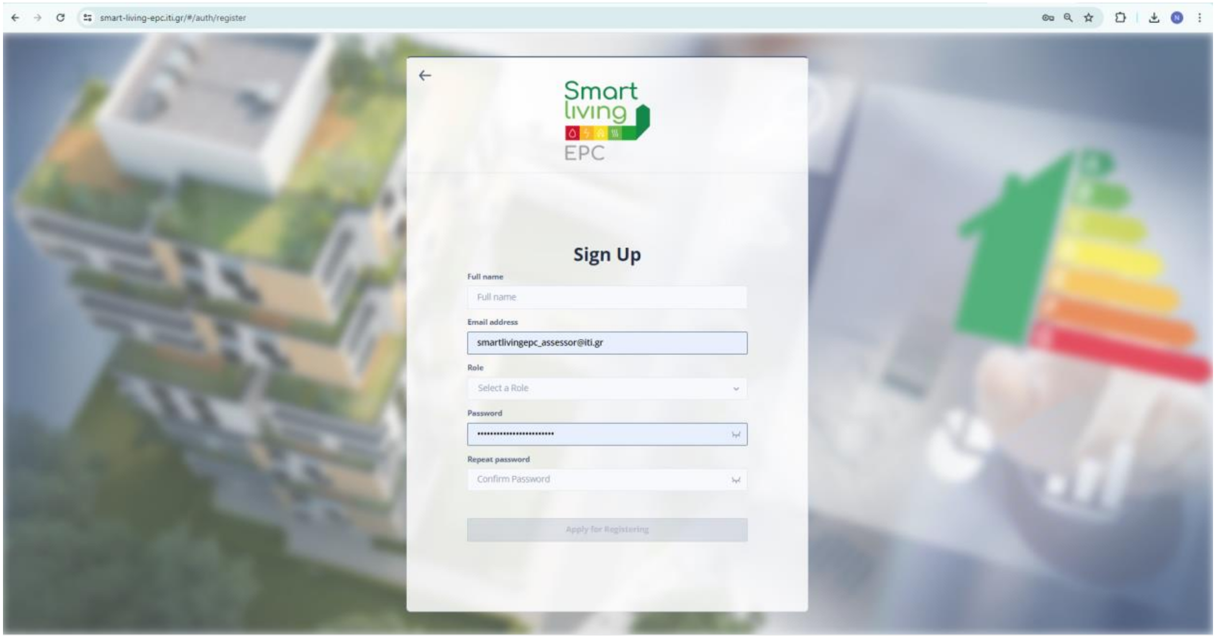


Figure 6. SmartLivingEPC Web Platform. Landing Page. Sign Up.

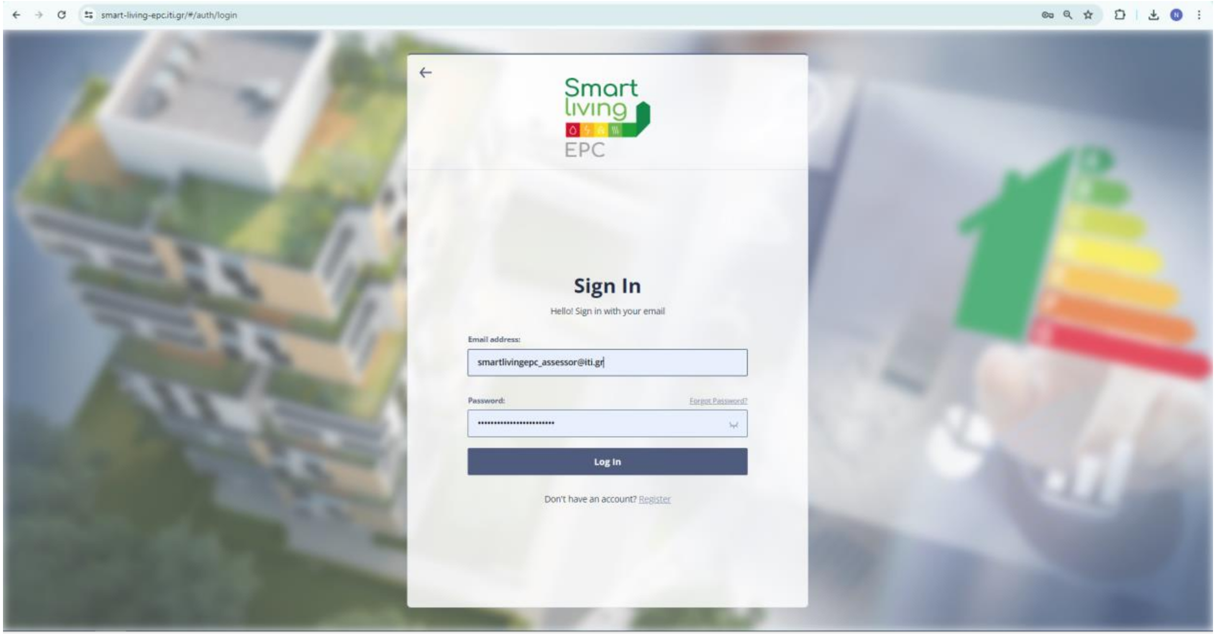


Figure 7. SmartLivingEPC Web Platform. Landing Page. Sign In.

In case of a missing password, an email can be sent using the corresponding recovery page (Figure 8) to enable the password reset.

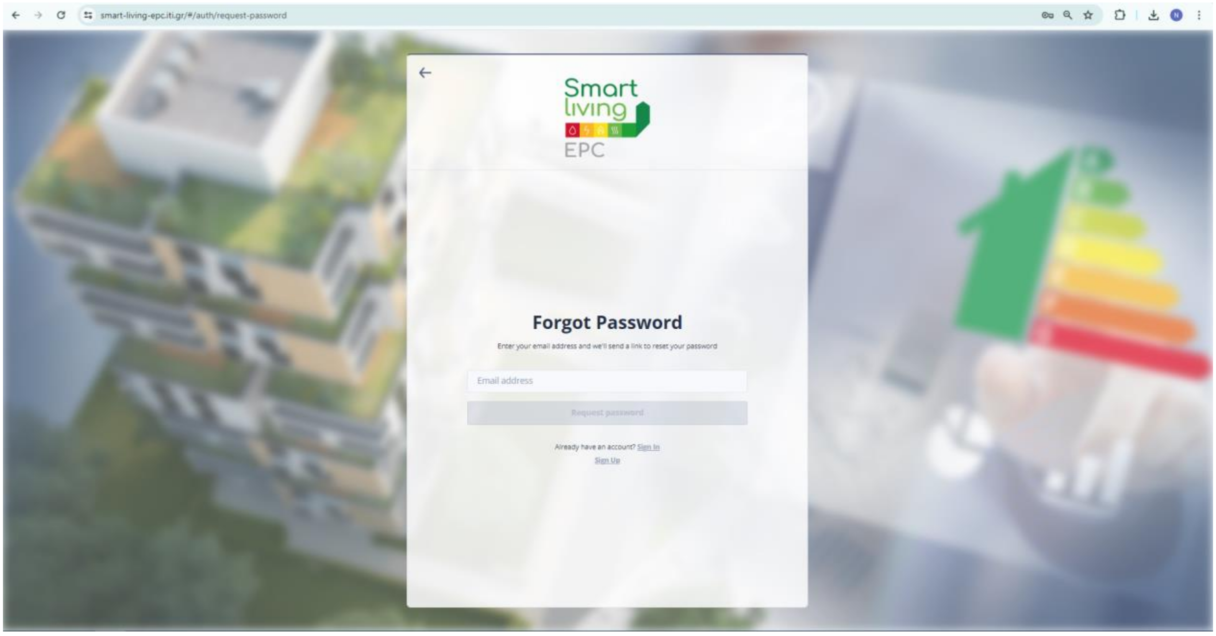


Figure 8. SmartLivingEPC Web Platform. Landing Page. Password Recovery Page.

Once on the SmartLivingEPC Web Platform main dashboard, first-time users are required to verify the email address (Figure 9). Otherwise, several features of the platform are not available.

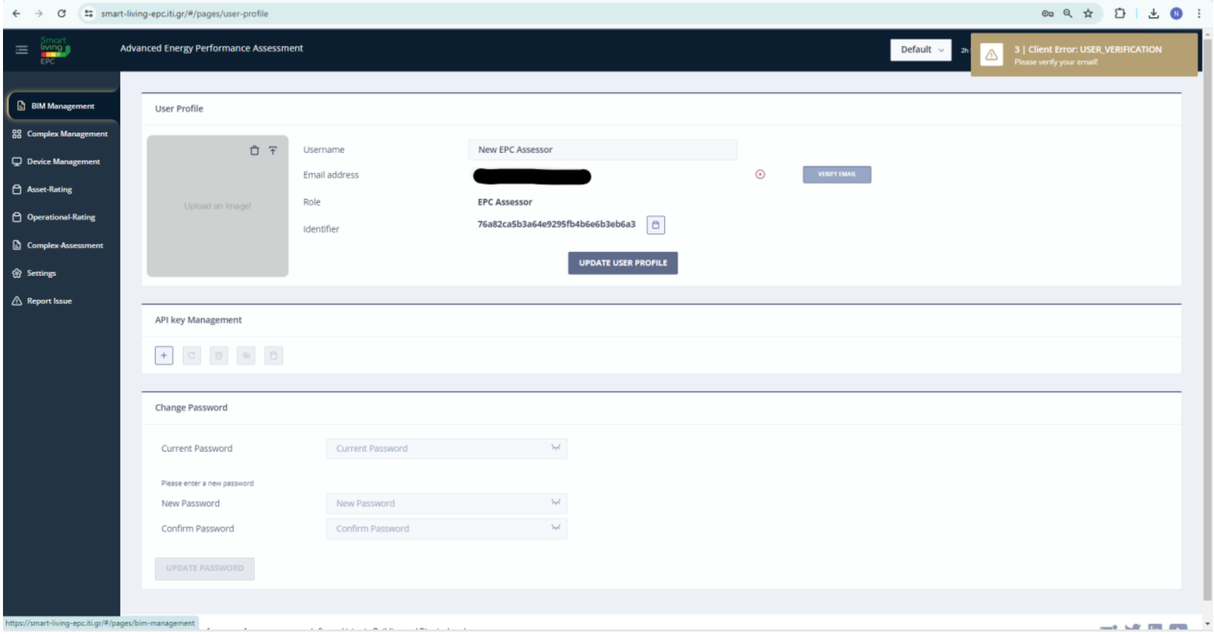


Figure 9. SmartLivingEPC Web Platform. Main Dashboard. Email verification.

3.1.3 User Roles and Permissions

Access to features and actions within the Smart Living EPC Web Platform is determined by user roles, which are selected during the registration process. Each role grants a specific set of permissions tailored to the user's responsibilities and needs.

3.1.3.1 EPC Assessor (Main Role)

The EPC Assessor has full access to all functionalities related to building performance assessments. This role includes permissions to:

- Upload, validate, and manage BIM files
- Create and manage building units and complexes
- Register and configure monitoring devices for building units and complexes.
- Set up and calculate both asset and operational ratings for buildings and complexes

3.1.3.2 Building Tenant

The Building Tenant has a view-only role within the platform. Users in this role can:

- Access and view building units or complexes
- Review building performance assessment results

  However, they cannot upload, edit, or create any new content or configurations.

3.1.3.3 Authority User

Designed for organizations or institutions with oversight responsibilities (e.g., regional or national authorities), the Authority role provides extended view access across multiple buildings. While similar to the Building Tenant role, it allows broader visibility over the building stock without editing rights.

3.1.3.4 System Administrator

The System Administrator has full access to all platform functionalities. This includes:

- Managing user accounts and roles
- Viewing and editing all uploaded building performance data
- Overseeing the overall operation and configuration of the platform

3.1.4 Dashboard Overview

The main dashboard is accessed by users after login (Figure 10). It includes a navigation pane, which is visible and active in all interfaces of the SmartLivingEPC Web Platform. On the top right corner, the **profile page** may be accessed.

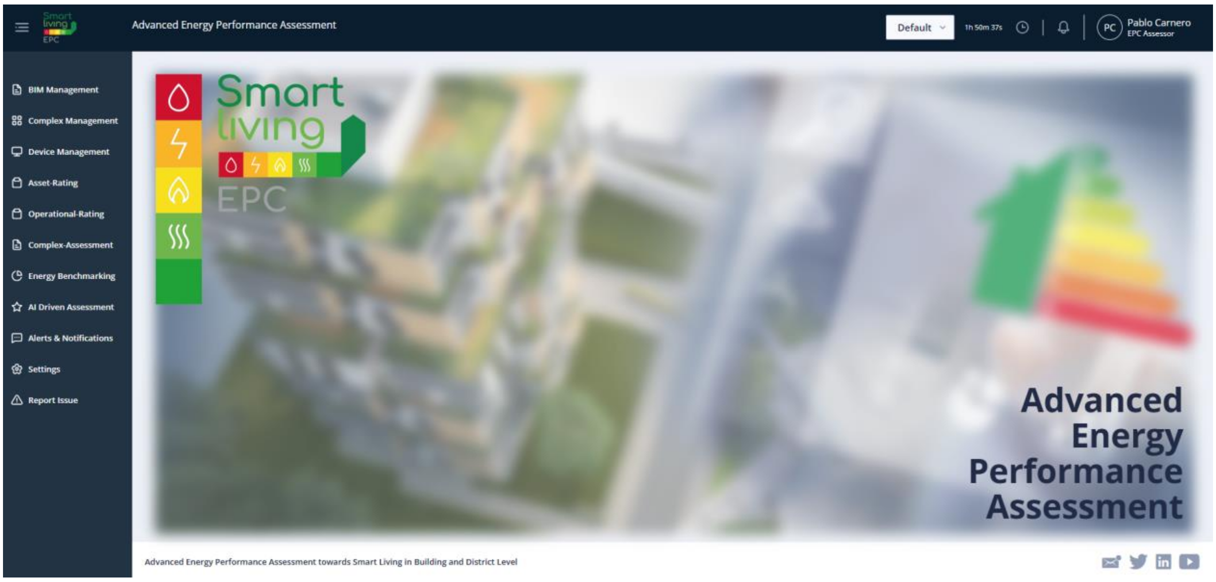


Figure 10. SmartLivingEPC Web Platform. Main Dashboard. Overview.

The additional dashboards, which may be accessed through the navigation menu to the left, are:

- BIM Management
- Complex Management
- Device Management
- Asset Rating
- Operational Rating
- Complex Assessment
- Energy Benchmarking
- AI Driven Assessment
- Alerts & Notifications
- Settings
- Report Issue

The language used in the platform is English. No accessibility settings are included.

3.2 Core Features

In the next sections the user experience vis-à-vis the interfaces of the SmartLivingEPC platform is described.

Additionally, from the **profile page** a personalised API key can be obtained for accessing various platform services directly. This functionality facilitates coordination with third-party application that require the execution and retrieval of assessment results.

3.2.1 BIM Management

From the **BIM Management** dashboard (Figure 11), digital building models (i.e., IFC files) can be uploaded seamlessly. Upon upload, the SmartLivingEPC Web Platform validates the digital building model's compliance with the set of minimum requirements required from the methodology perspective. The platform issues an error message flagging non-compliance.

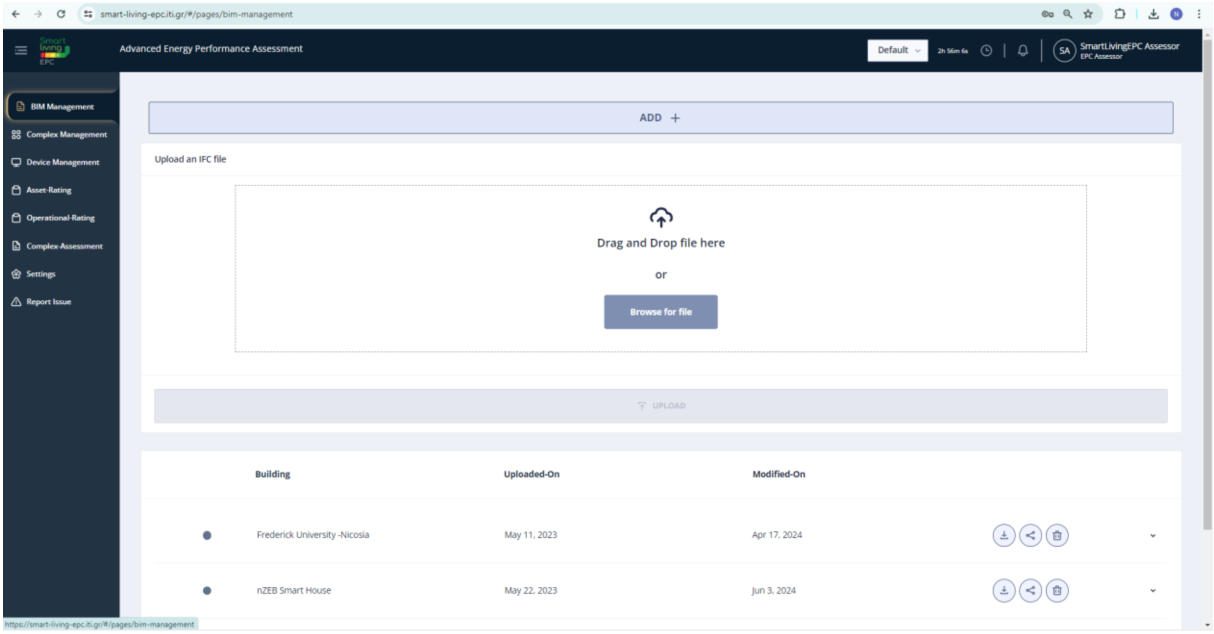


Figure 11. SmartLivingEPC Web Platform. BIM Management Dashboard. Overview.

Digital building models are transmitted to the CIEM database for storage. Stored digital building models can be managed from the BIM Management Dashboard (Figure 12). Many actions can be applied to stored digital building models, such as modifying the building name and its location (Figure 13). Moreover, stores files can be shared with other users of the platform.

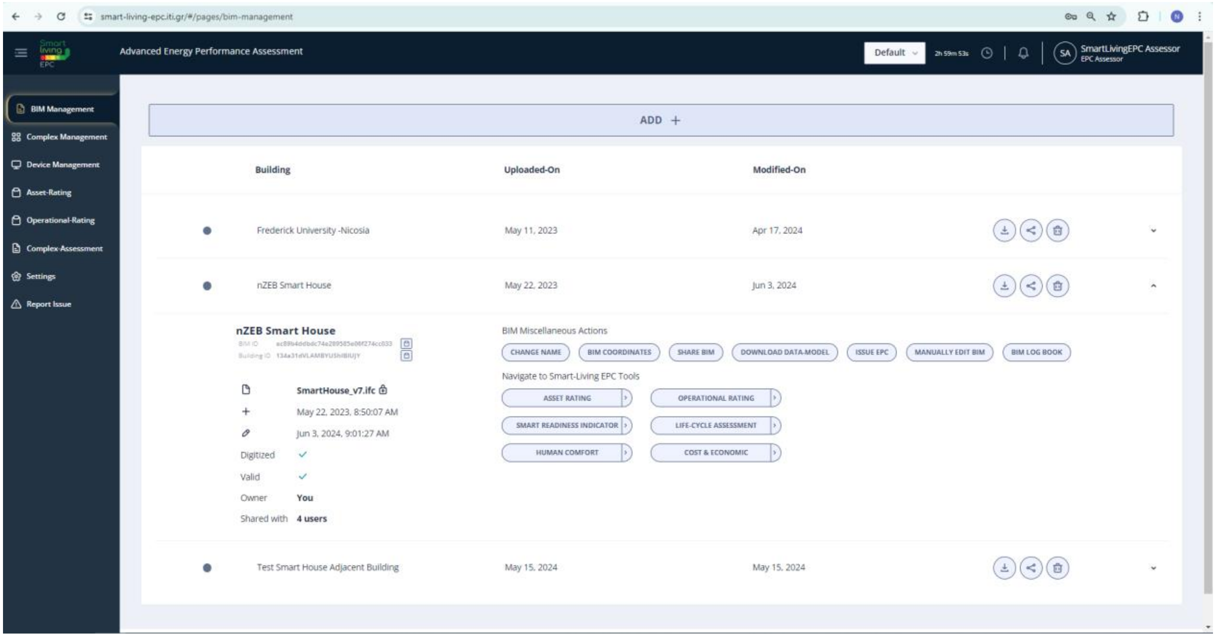


Figure 12. SmartLivingEPC Web Platform. BIM Management Dashboard. Stored files.

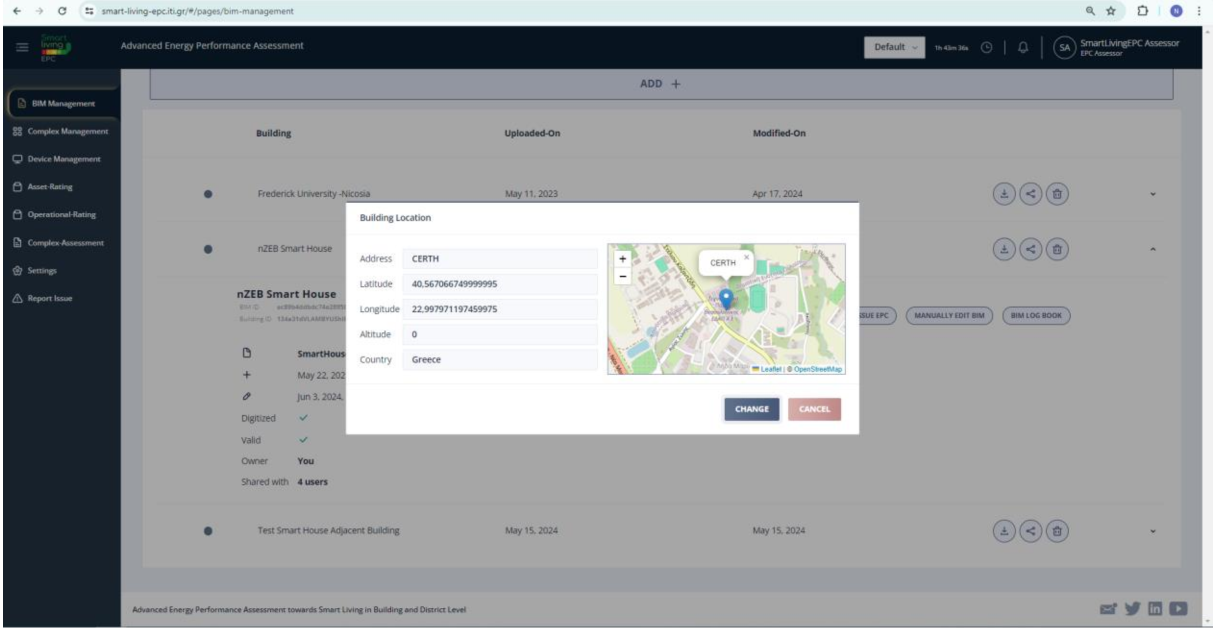


Figure 13. SmartLivingEPC Web Platform. BIM Management Dashboard. Edition of location.

Stored digital building models may be edited through the “Edit BIM” functionality. Upon action, a file editing form pops up enabling the user to modify certain parameters (Figure 14). The main application of this feature is the integration of information from technical building audits, which may update inputs for the asset assessment at the building level (methodology developed in the scope of Task 2.4).

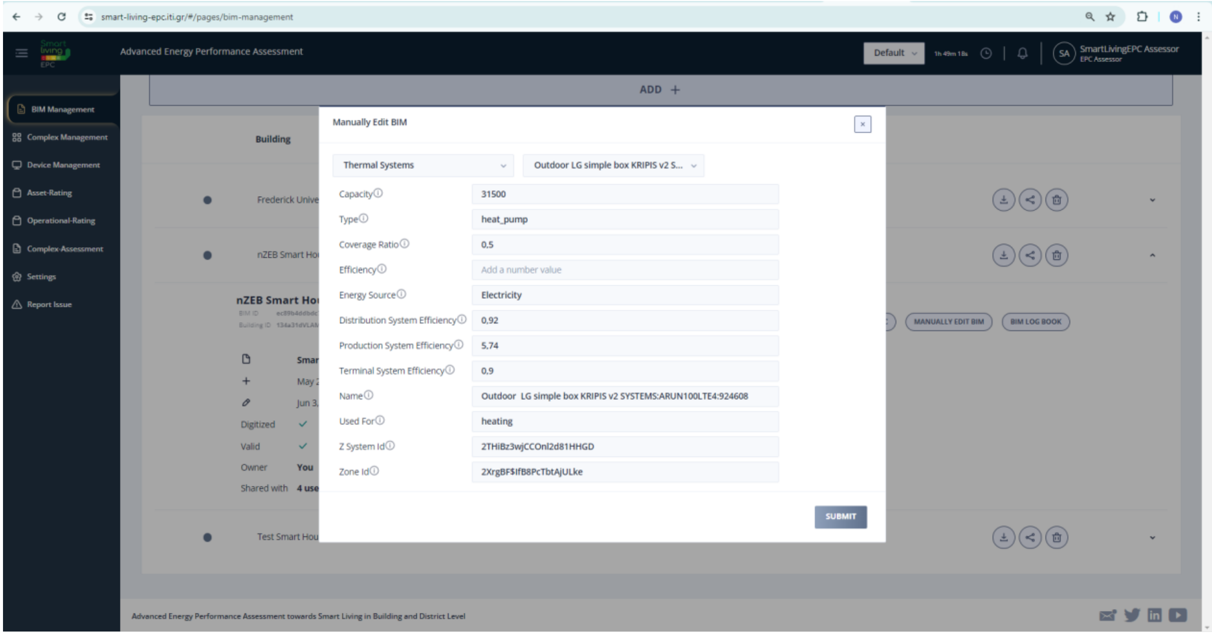


Figure 14. SmartLivingEPC Web Platform. BIM Management Dashboard. Edition of BIM file.

Lastly, the **BIM Management** Dashboard provides access to the digital building logbook (Figure 15).

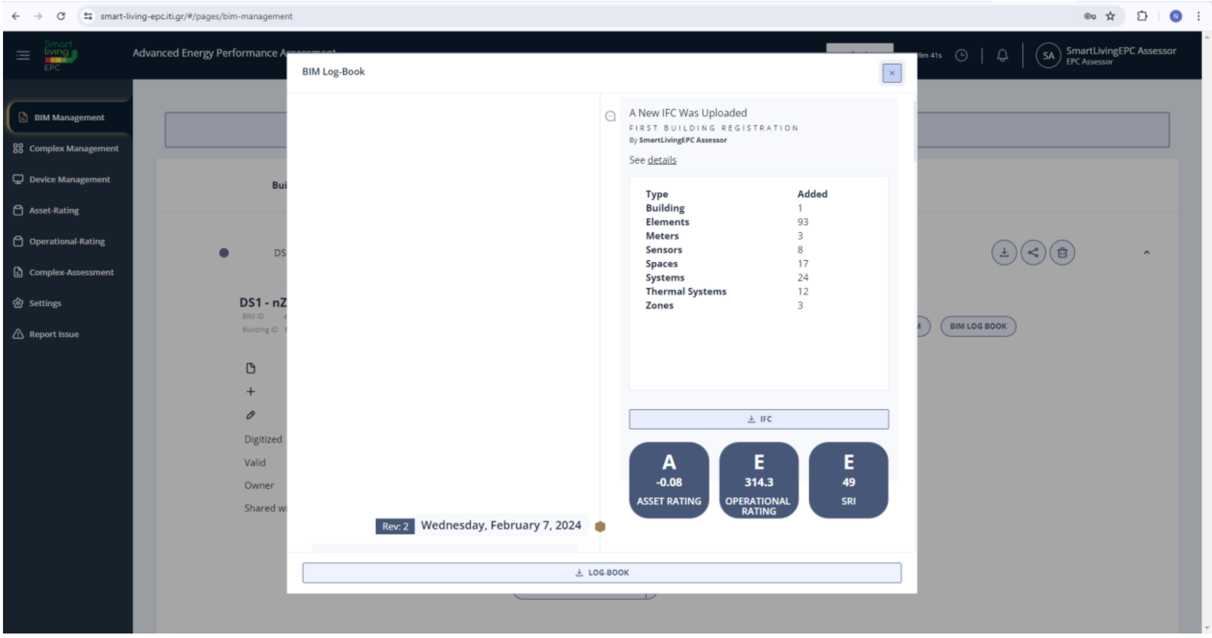


Figure 15. SmartLivingEPC Web Platform. BIM Management Dashboard. Digital Building Logbook.

The logbook accumulates information on the building from the first upload to the SmartLivingEPC Web Platform. It includes all the detailed changes that have been applied to the digital building model, including the assessment results corresponding to each revision.

3.2.2 Building Complex Management

From the **Building Complex Management** dashboard (Figure 16), digital models of individual buildings (i.e., IFC files) can be grouped to form building complexes. Herein, users can select a registered building to act as the complex formation basis then draw a polygon around its location on an interactive map. Nearby buildings that are enclosed with the polygon and have been digitally instantiated as shown in the previous section, are automatically retrieved and added to the complex, as depicted in Figure 17.

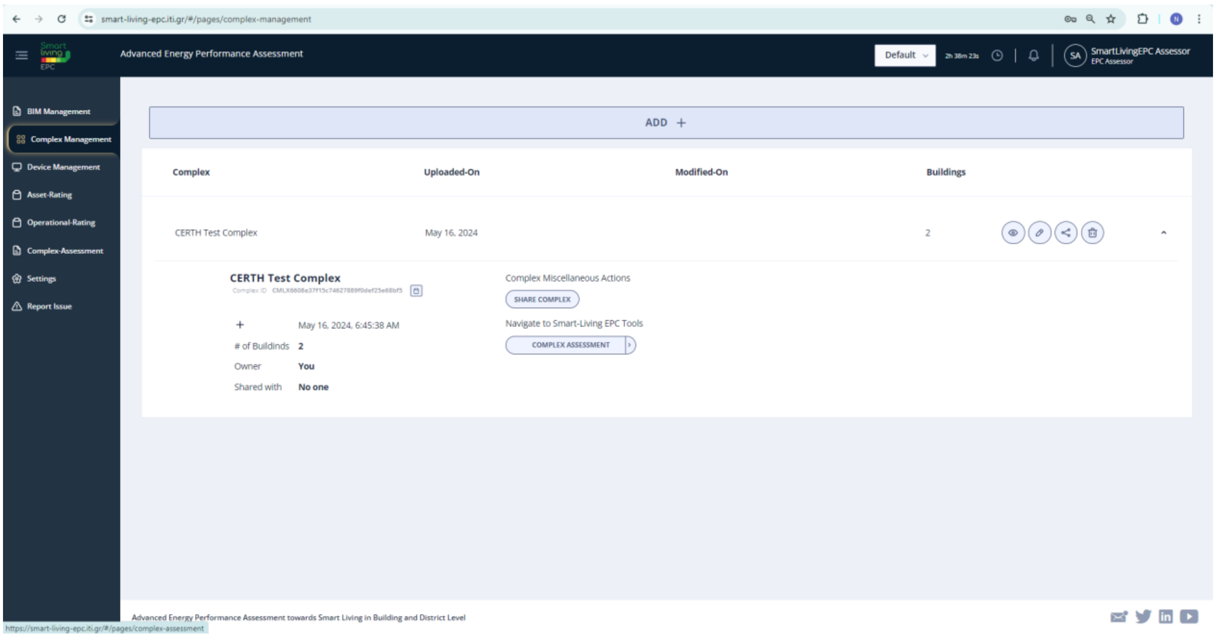


Figure 16. SmartLivingEPC Web Platform. Complex Management Dashboard. Overview.

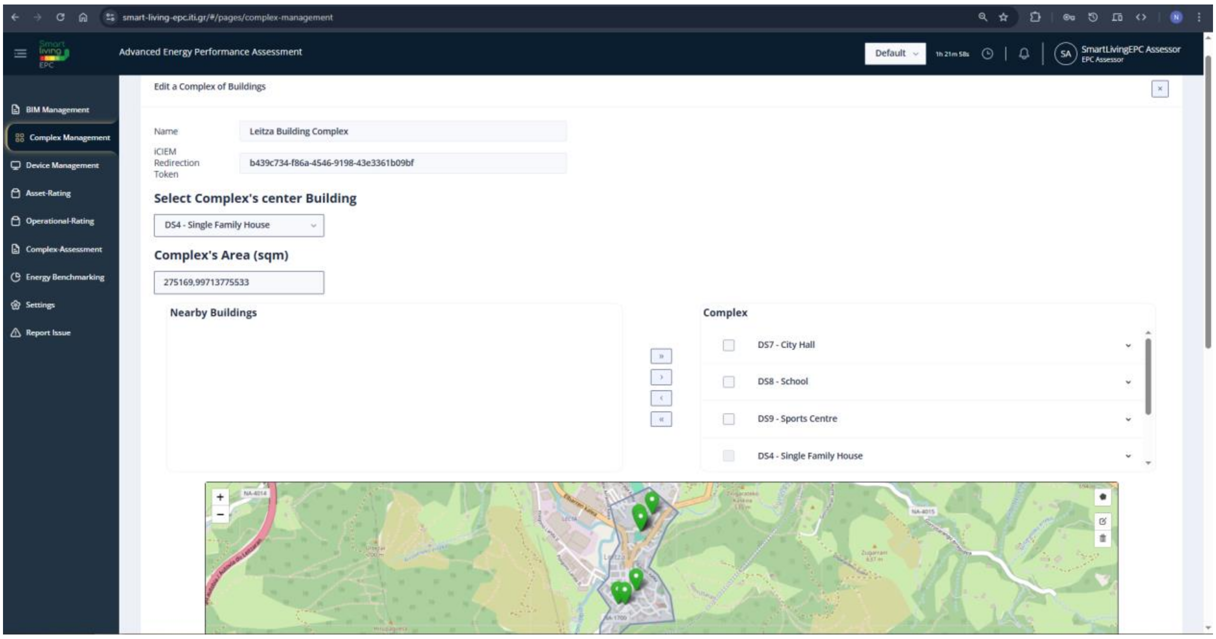


Figure 17. SmartLivingEPC Web Platform. Complex Management Dashboard. Complex set-up.

Upon setup, the new building complex can be shared with other users as a whole, without requiring sharing of the individual buildings within.

3.2.3 Device Management

From the **Device Management** dashboard (Figure 18), monitoring devices – inferred from the digital models of buildings (i.e., IFC files) or manually defined - can be managed.

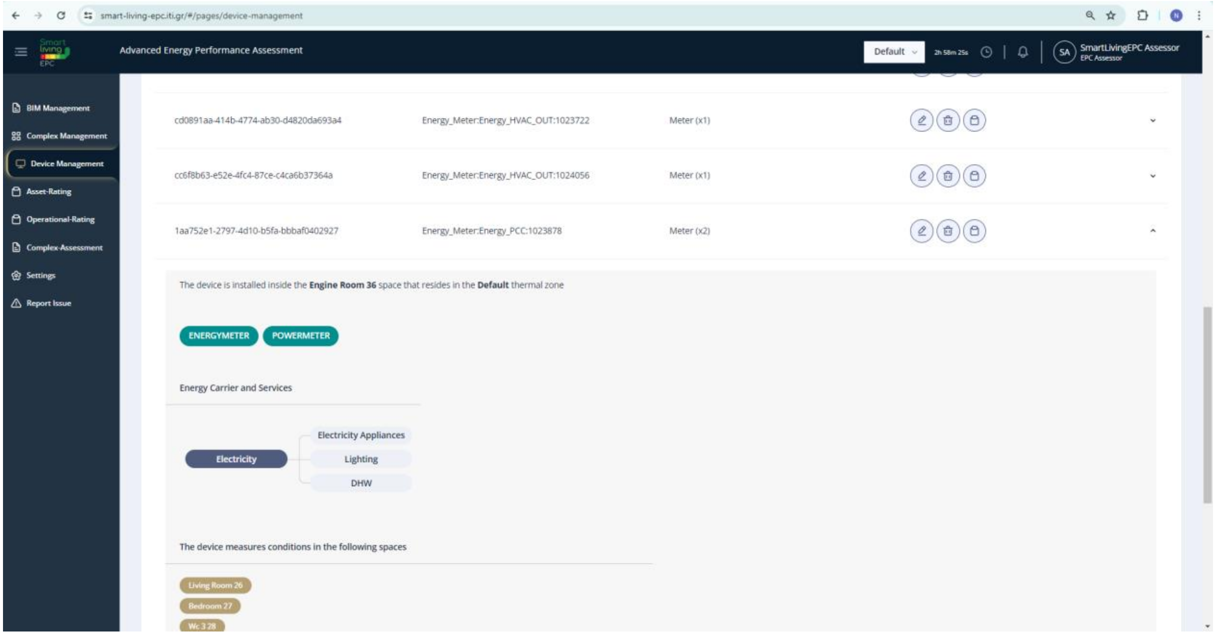


Figure 18. SmartLivingEPC Web Platform. Device Management Dashboard. Overview.

The registration of a new device and the edition of a pre-existing one is made through a dedicated wizard. The first step is the configuration of the device type (i.e., sensor or meter). For metering devices, the monitored energy carrier shall also be defined (top left in Figure 19). Next, the defined device shall be assigned to a thermal zone and space of the digital building model. For metering devices, the technical building systems linked to it shall be defined (top right in Figure 19). Lastly, a name and unique device ID ought to be assigned, with the latter used to match the static representation of the device in the building instance with real-time measurements provided by the CIEM (bottom left in Figure 19).

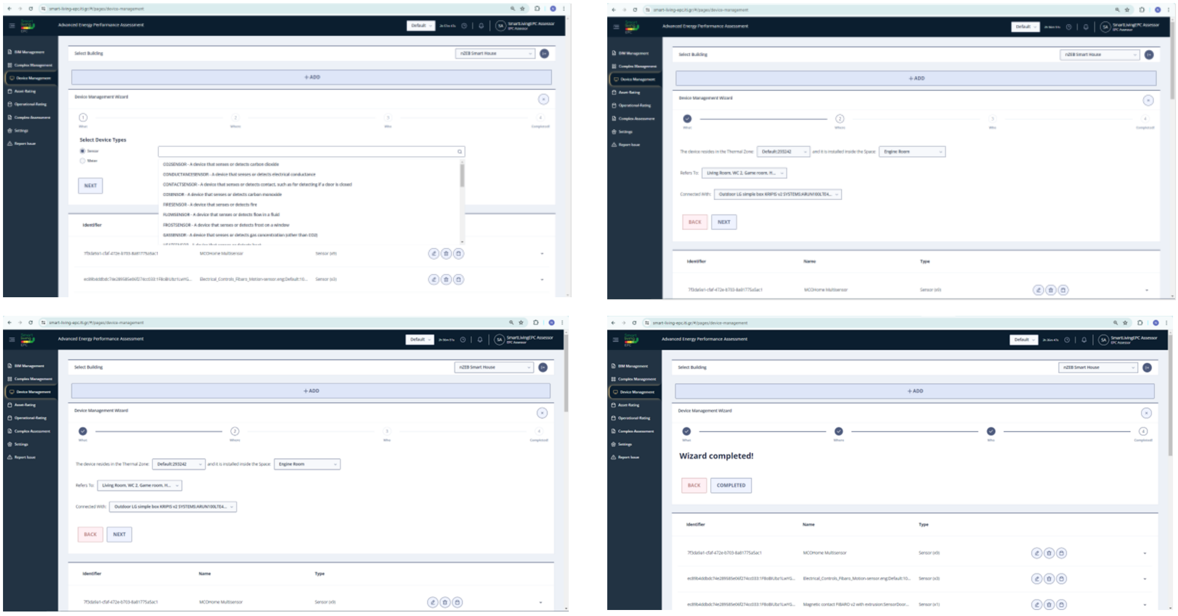


Figure 19. SmartLivingEPC Web Platform. Device Management Dashboard. Wizard.

3.2.4 Asset Rating

The asset assessment at the building level is performed in the **Asset Rating** dashboard (Figure 20).

Upon first click, a validation of the digital building model is triggered. This process identifies missing parameters which are required for the assessment. In case of missing information, users are prompted to provide it (Figure 21).

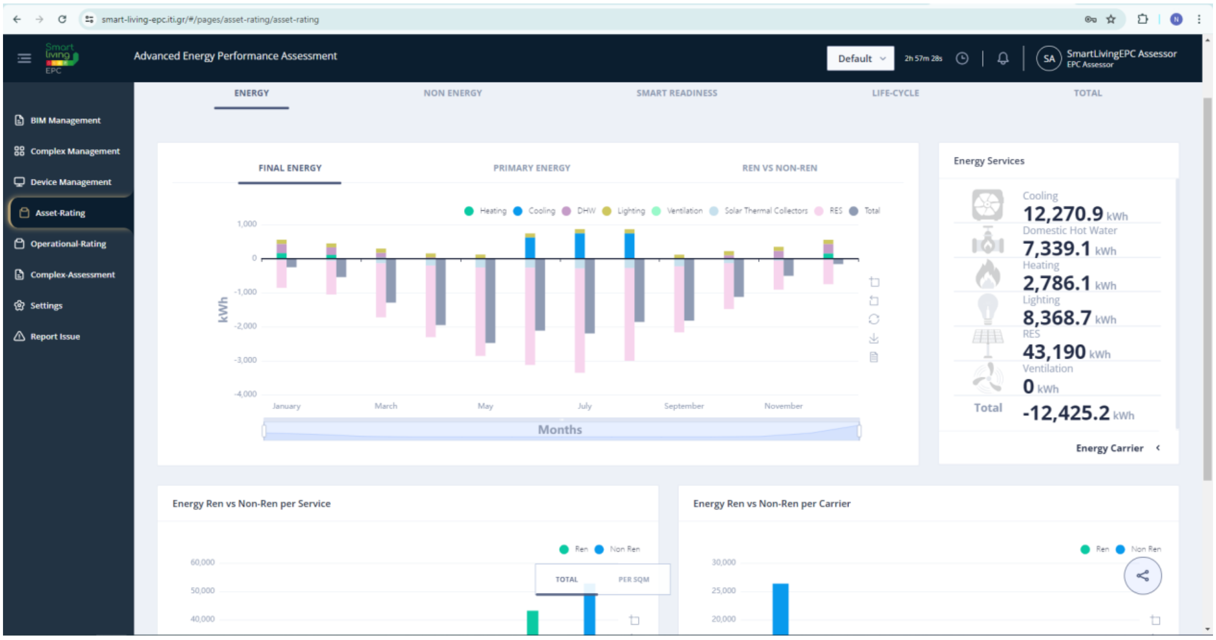


Figure 20. SmartLivingEPC Web Platform. Asset Rating Dashboard. Energy. Indicators.

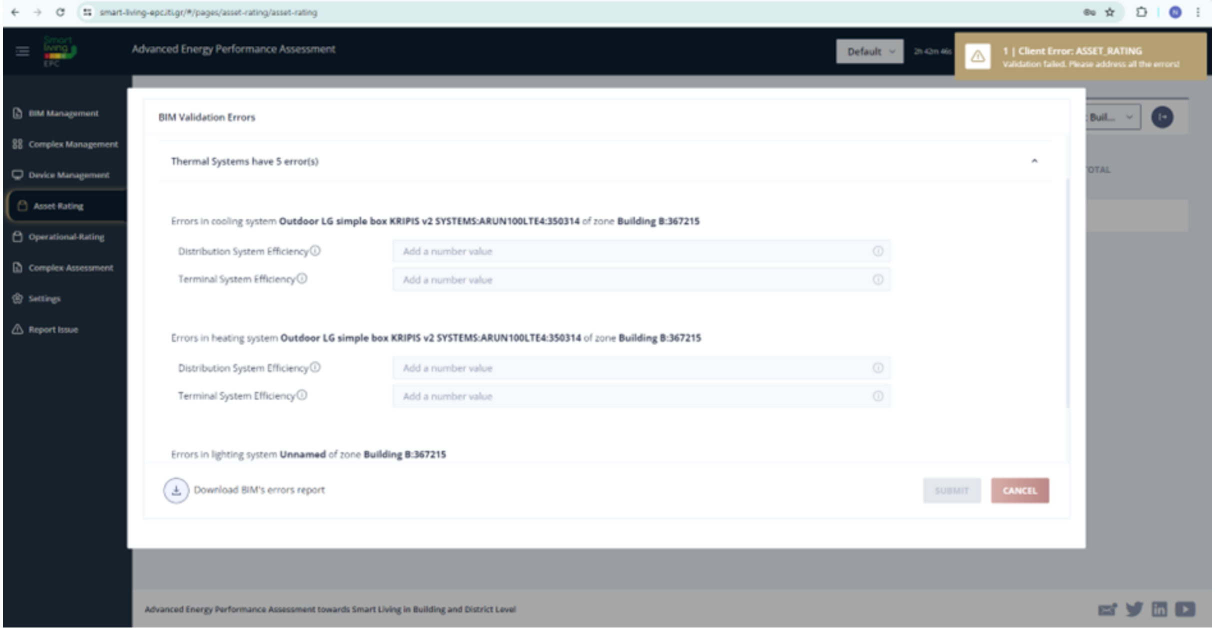


Figure 21. SmartLivingEPC Web Platform. Asset Rating Dashboard. Input Validation.

The results of the assessment are displayed per dimension (Energy, IEQ, Smart Readiness, and Sustainability) and overall. For each dimension, there are overall and partial indicators. The different dimensions may be accessed through the tabs at the top of the page.

The **energy** dimension (Figure 20) features final and primary energy indicators, as well as comparative between renewable and non-renewable primary energy. The results are displayed per service in a monthly graph. In addition, there is information per energy carrier.

The **non-energy** tab includes the assessment related to IEQ, which is divided into thermal, acoustic and visual comfort, and IAQ. For each category, users should first configure assessment zones, which are created by selecting several building spaces and providing all the necessary input parameters needed for the calculation. Inputs related to zone geometry (i.e., area, volume, window area) are automatically inferred from the digital building model. Figure 22 shows the definition of an acoustic assessment zone for illustrative purposes. For the rest of subcategories, the process and user experience are similar.

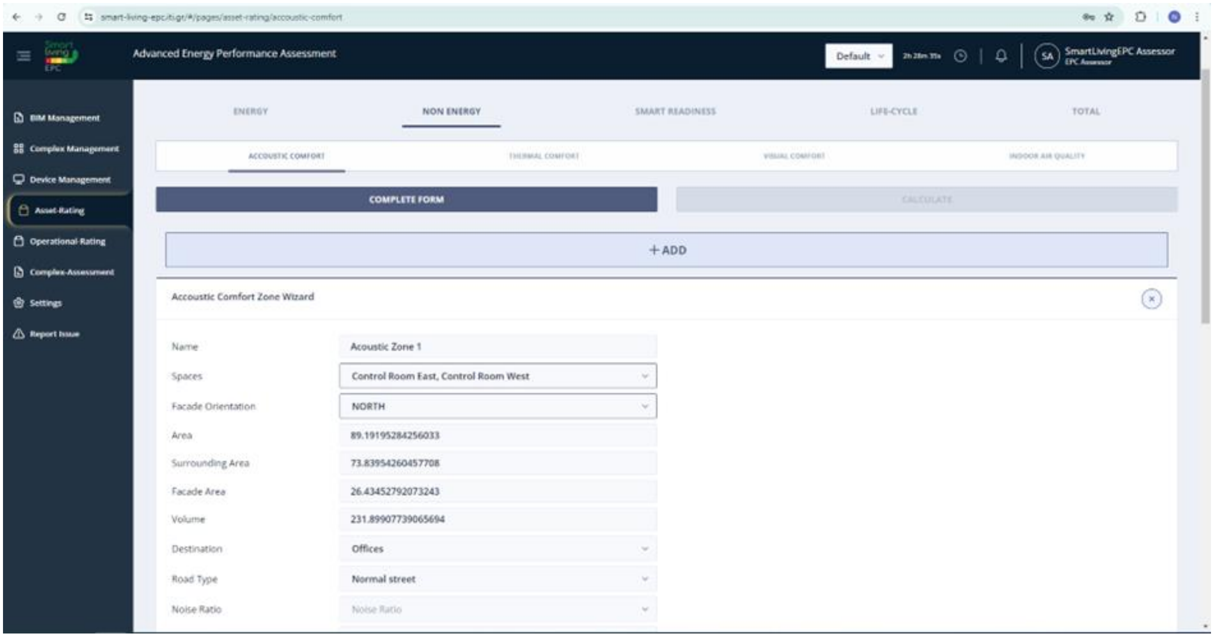


Figure 22. SmartLivingEPC Web Platform. Asset Rating Dashboard. Non-energy. Assessment Zone Definition.

Upon completion of the input parameter definition, the calculations can be run. As a result, the non-energy indicators for each of the subcategories are obtained as depicted in Figure 23. Different visualisation of the results exists for each subcategory: acoustic comfort (top left), thermal comfort (top right), visual comfort (bottom left) and IAQ (bottom right).

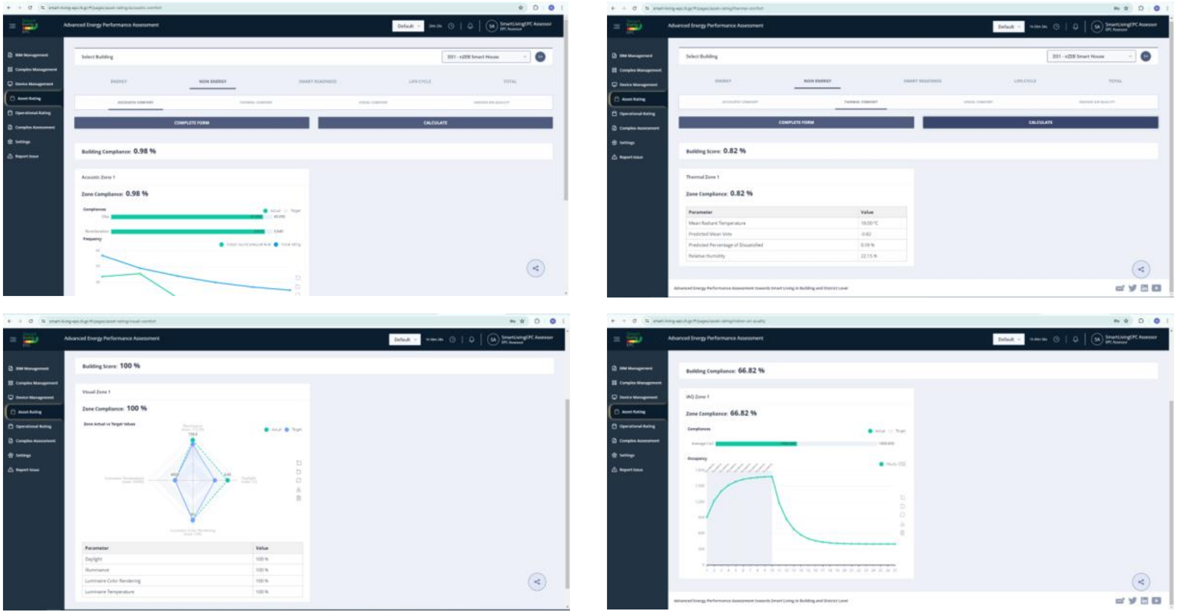


Figure 23. SmartLivingEPC Web Platform. Asset Rating Dashboard. Non-energy. Indicators.

The **smart readiness** tab enables the assessment of the smart readiness indicator. Through a wizard, users shall define the input data which could not be inferred from the digital building model. The data requiring user input or validation generally includes the assessor information (**Figure 24**), the building characteristics (**Figure 25**), and the bulk of the assessment consisting of the definition of technical domain presence, smart-ready service applicability, and functionality levels (**Figure 26**).

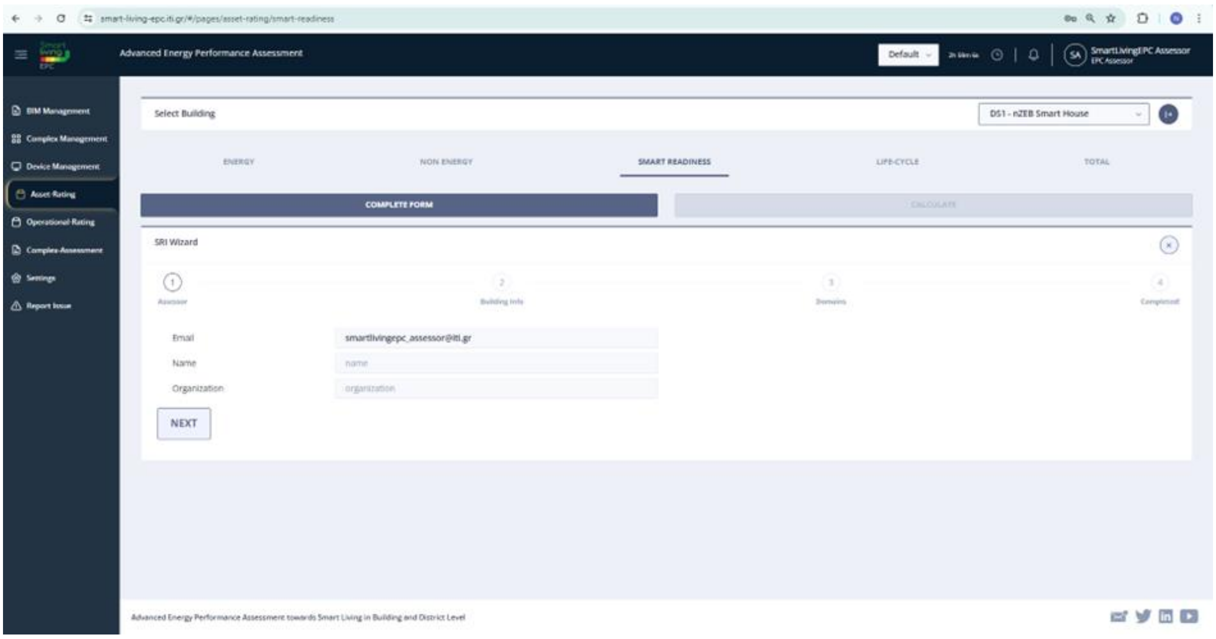


Figure 24. SmartLivingEPC Web Platform. Asset Rating Dashboard. Smart Readiness. Assessor Information.

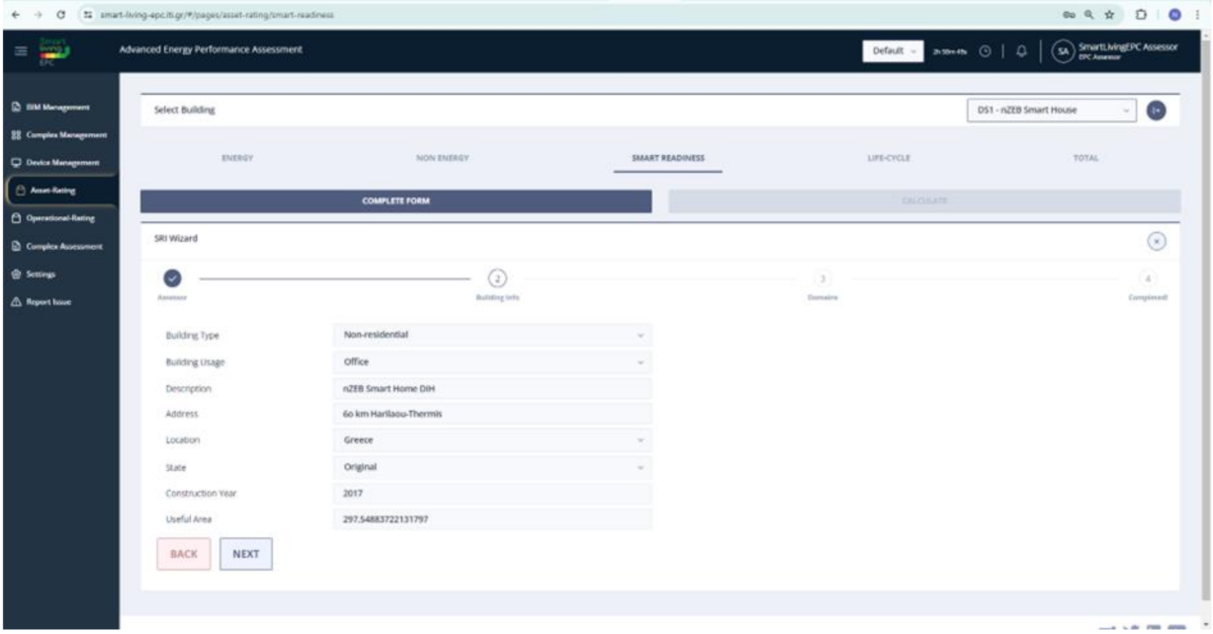


Figure 25. SmartLivingEPC Web Platform. Asset Rating Dashboard. Smart Readiness. Building Information.

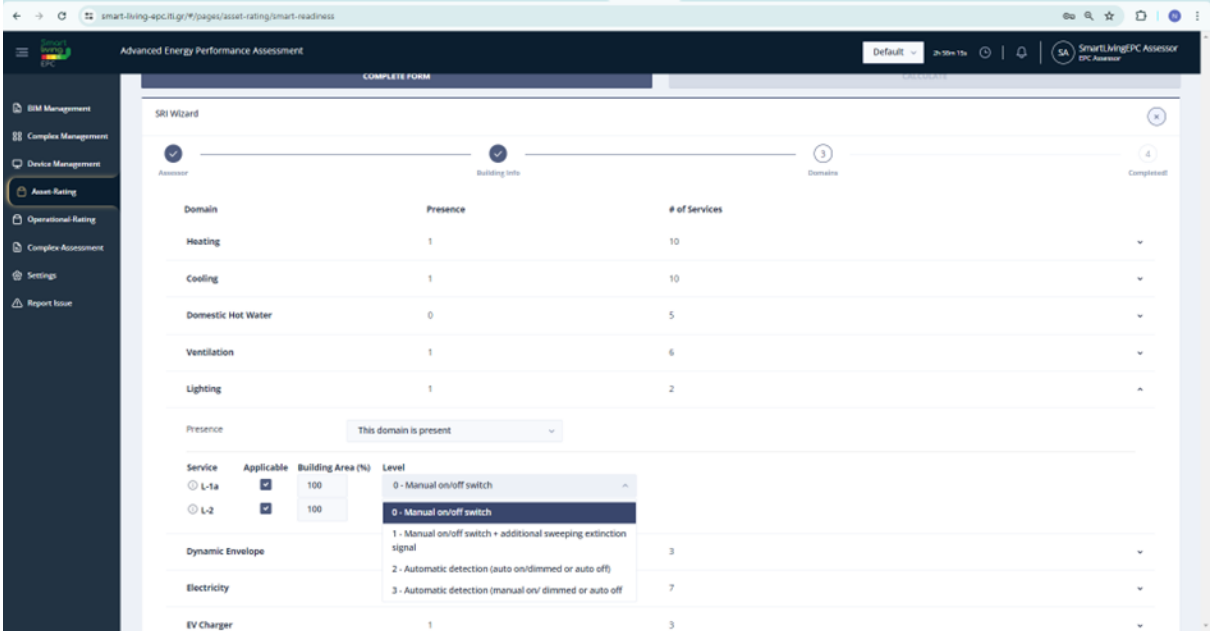


Figure 26. SmartLivingEPC Web Platform. Asset Rating Dashboard. Smart Readiness. Technical Domains, Services and Functionality Levels.

As a result of the assessment, the indicators depicted in **Figure 27** are obtained.

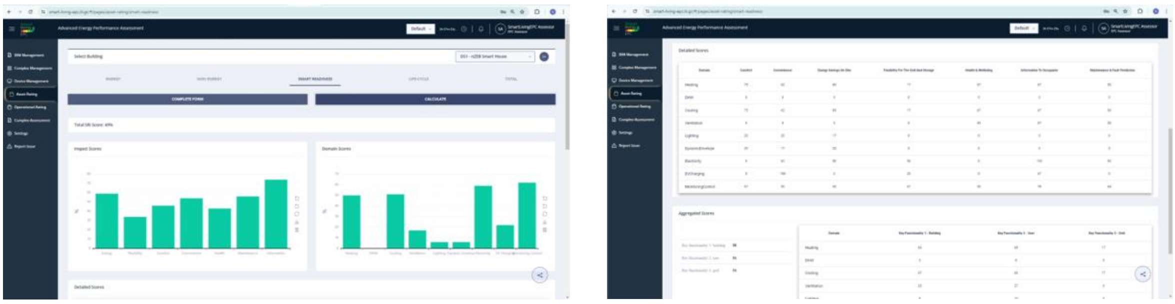


Figure 27. SmartLivingEPC Web Platform. Asset Rating Dashboard. Smart Readiness. Indicators.

The **sustainability** assessment at the building level is performed in the life cycle tab. Based on the IFC information regarding the building construction materials, the user can perform a life-cycle assessment (LCA) of the building, to calculate its environmental footprint as defined by several performance indicators. The procedure is as follows.

1. The list of materials is initially loaded (Figure 28, top left), allowing the user to assign the Environmental Product Declarations (EPD) values for each material using two options.
2. By manually inserting the EPD data through the provided user forms or by uploading a .csv file containing the information in a predefined format (Figure 28, top right).
3. By searching for the material based on its name in an external EPD database aggregator (ECO Portal), as in (Figure 28, bottom left). Then, the required information is retrieved automatically, while the user can also be redirected to the corresponding EPD information page for more details (Figure 28, bottom right).

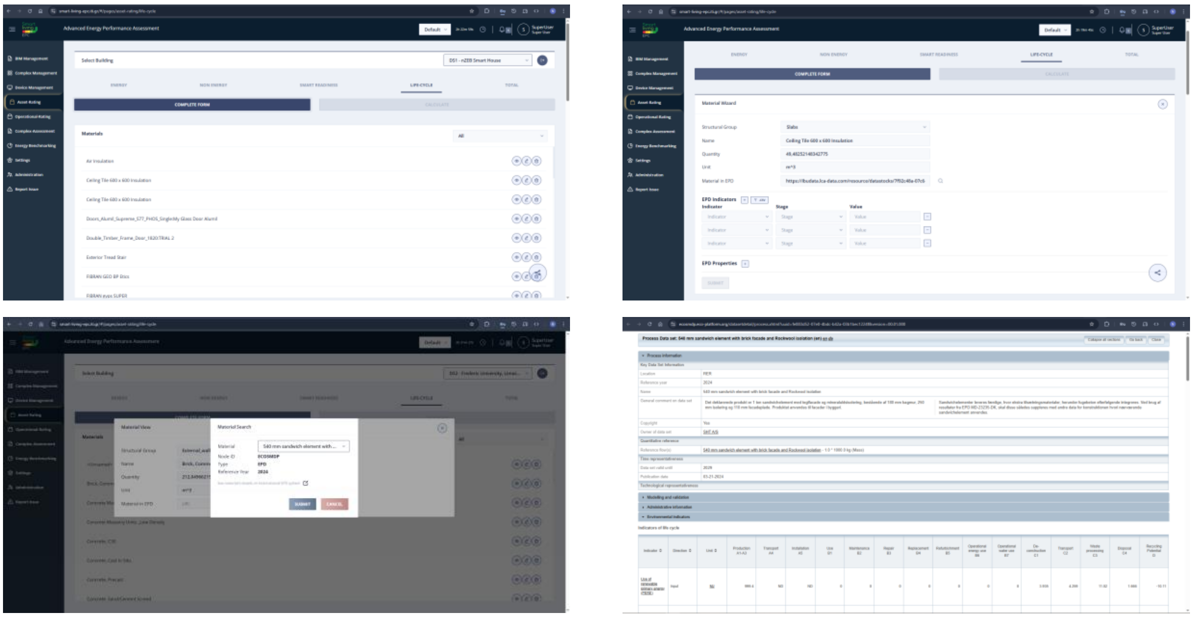


Figure 28. SmartLivingEPC Web Platform. Asset Rating Dashboard. Sustainability. Life-Cycle Assessment.

Following the completion of the EPD values setup, the user can execute the LCA calculations. The environmental impact results are grouped per material, life-cycle stage and structural group, while information regarding the building material quantities (i.e., mass) are also provided (Figure 29)

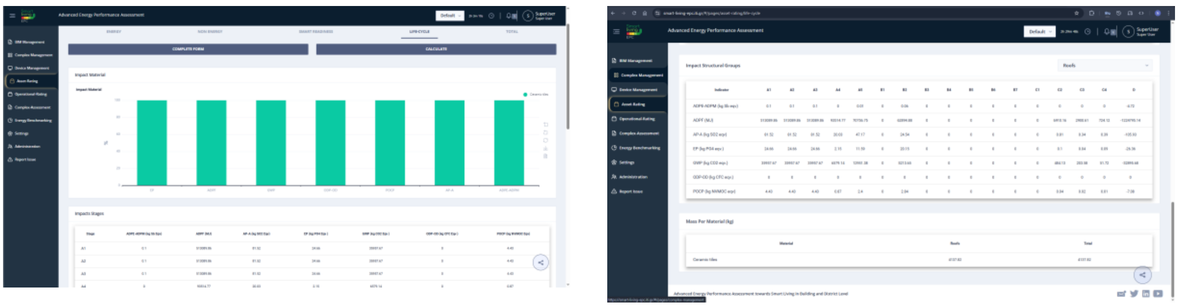
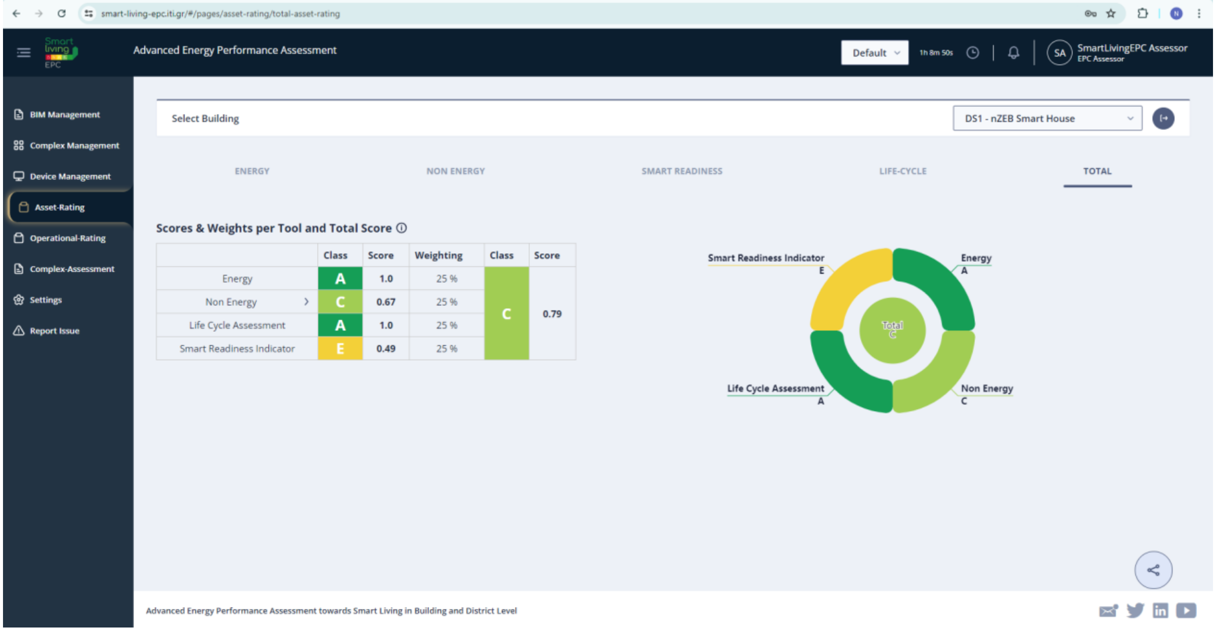


Figure 29. SmartLivingEPC Web Platform. Asset Rating Dashboard. Sustainability. Indicators.

The **overall asset assessment** is performed through the total tab. There, the results from each component are leveraged to obtain the overall asset assessment indicator and rating (Figure 30).



	Class	Score	Weighting	Class	Score
Energy	A	1.0	25 %	C	0.79
Non Energy	C	0.67	25 %		
Life Cycle Assessment	A	1.0	25 %		
Smart Readiness Indicator	E	0.49	25 %		

Figure 30. SmartLivingEPC Web Platform. Asset Rating Dashboard. Overall Indicators.

3.2.5 Operational Rating

The operational assessment at the building level is performed in the **Operational Rating** dashboard (Figure 31).

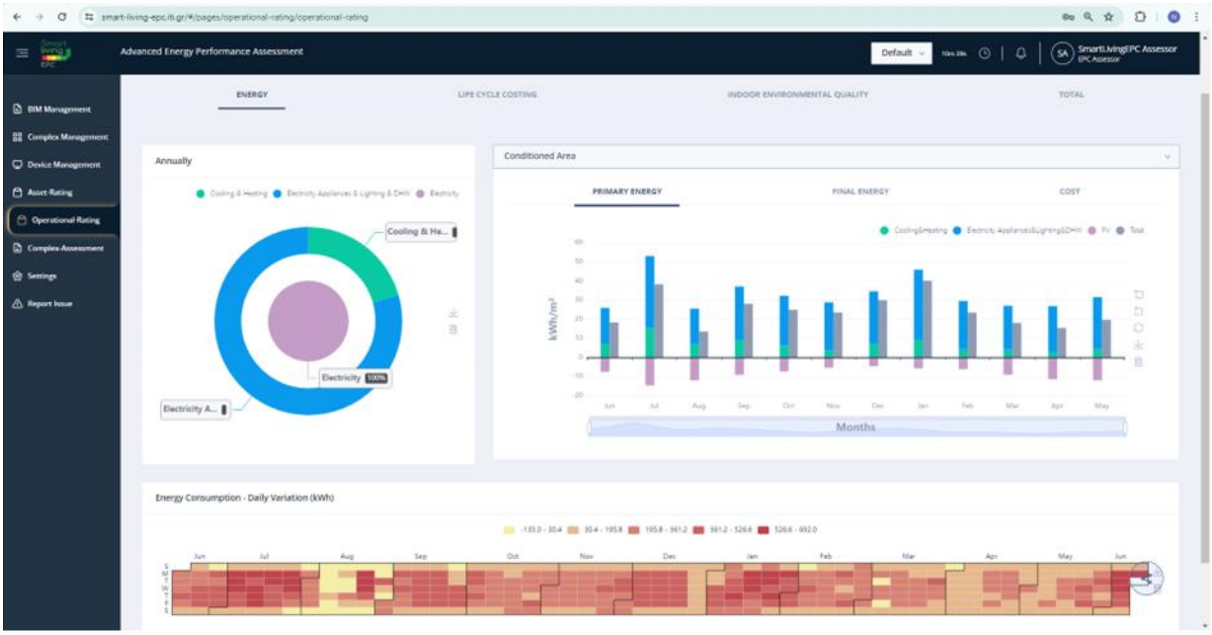


Figure 31. SmartLivingEPC Web Platform. Operational Rating Dashboard. Energy. Indicators.

The results of the assessment are displayed per dimension (Energy, Sustainability, IEQ) and overall. For each dimension, there are overall and partial indicators. The different dimensions may be accessed through the tabs at the top of the page.

The **energy** dimension (Figure 31) features final and primary energy indicators, as well as cost indicators. The results are displayed per service in an annual graph. In addition, there is information per energy carrier and daily variation.

The **life cycle costing** tab includes the assessment related to cost and economic indicators.

Prior to executing the calculations, users ought to assign a monthly pricing scheme for each energy carrier applicable to the building object of the assessment (Figure 32). Consequently, the as-designed and as-operated building costs are determined, leveraging the asset and operational indicators.

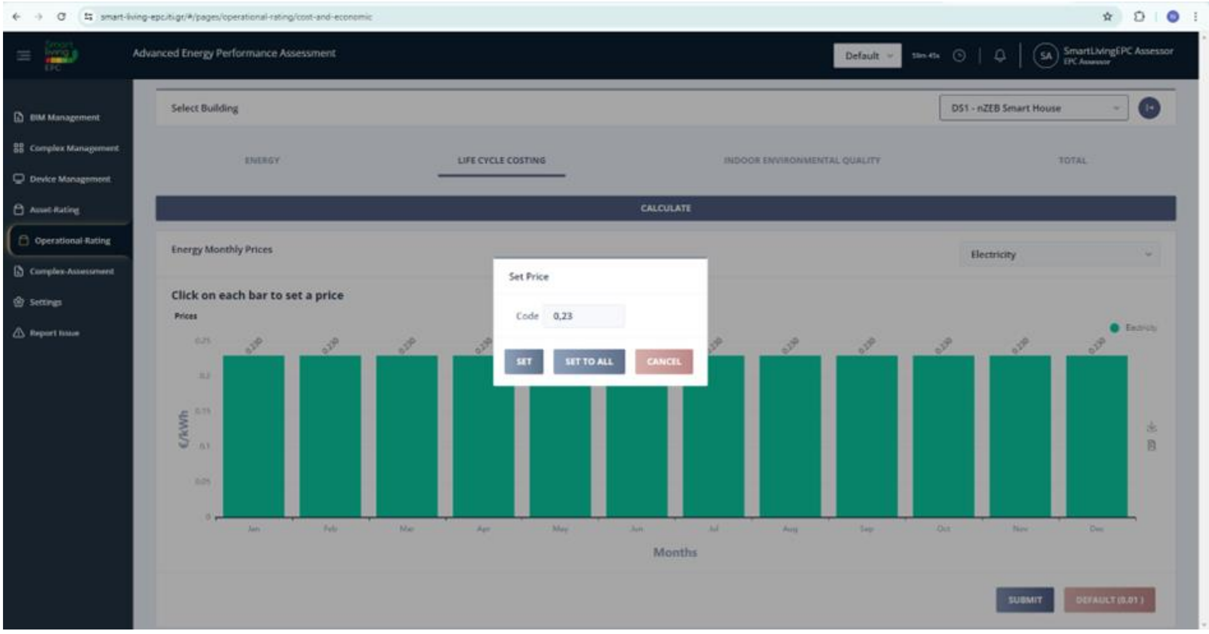


Figure 32. SmartLivingEPC Web Platform. Asset Rating Dashboard. Life Cycle Costing. Cost Definition.

Upon completion of the input parameter definition, the calculations can be run. As a result, the cost indicators as depicted in Figure 33. It depicts the as-designed (top left) and as-operated costs (top right) and the as-predicted energy costs for the next ten years (bottom).

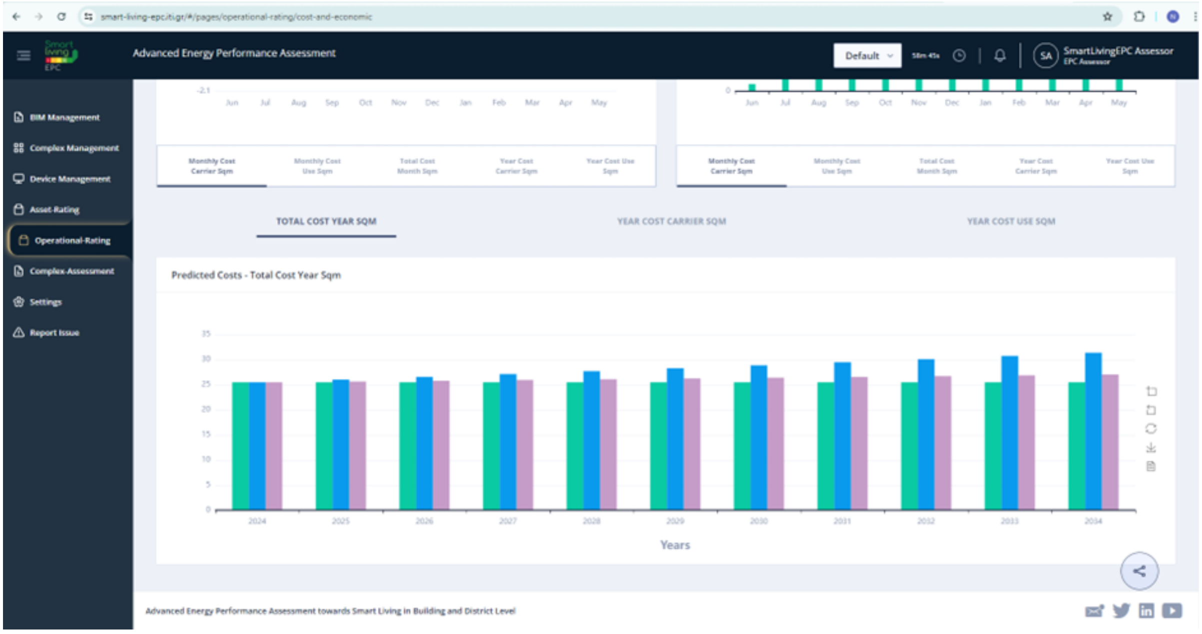


Figure 33. SmartLivingEPC Web Platform. Asset Rating Dashboard. Life Cycle Costing. Indicators.

The **IEQ** assessment at the building level is performed in the corresponding tab, which undertakes the setup and calculation of the indoor environmental quality indicators. They are divided into five distinct subcategories: indoor air quality, which includes carbon dioxide, particle material and virus risk assessments, occupant feedback and thermal comfort. Each category requires specific parameters setup in order to calculate the corresponding results.

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 geometry zone, i.e. area, volume, window area etc., are automatically determined based on BIM information.

The calculation of the **indoor air quality** related to **carbon dioxide** is performed per building space, which includes a sensing device that measures CO_2 concentration. The first step requires the setup of each assessment space (**Figure 34** top), where only appropriate spaces are provided to the user for selection. The area of each space is calculated automatically, while the user needs to enter the type and occupants of the space.

Upon completion of the setup process for the required spaces, the calculated results (per assessed space and in total) are presented to the user, as in **Figure 34** (bottom). By default, the results are calculated for the past six months of CO_2 concentration monitoring, though the user can adjust the calculation and repeat the assessment process by selecting a different time in the drop-down menu at the top right corner.

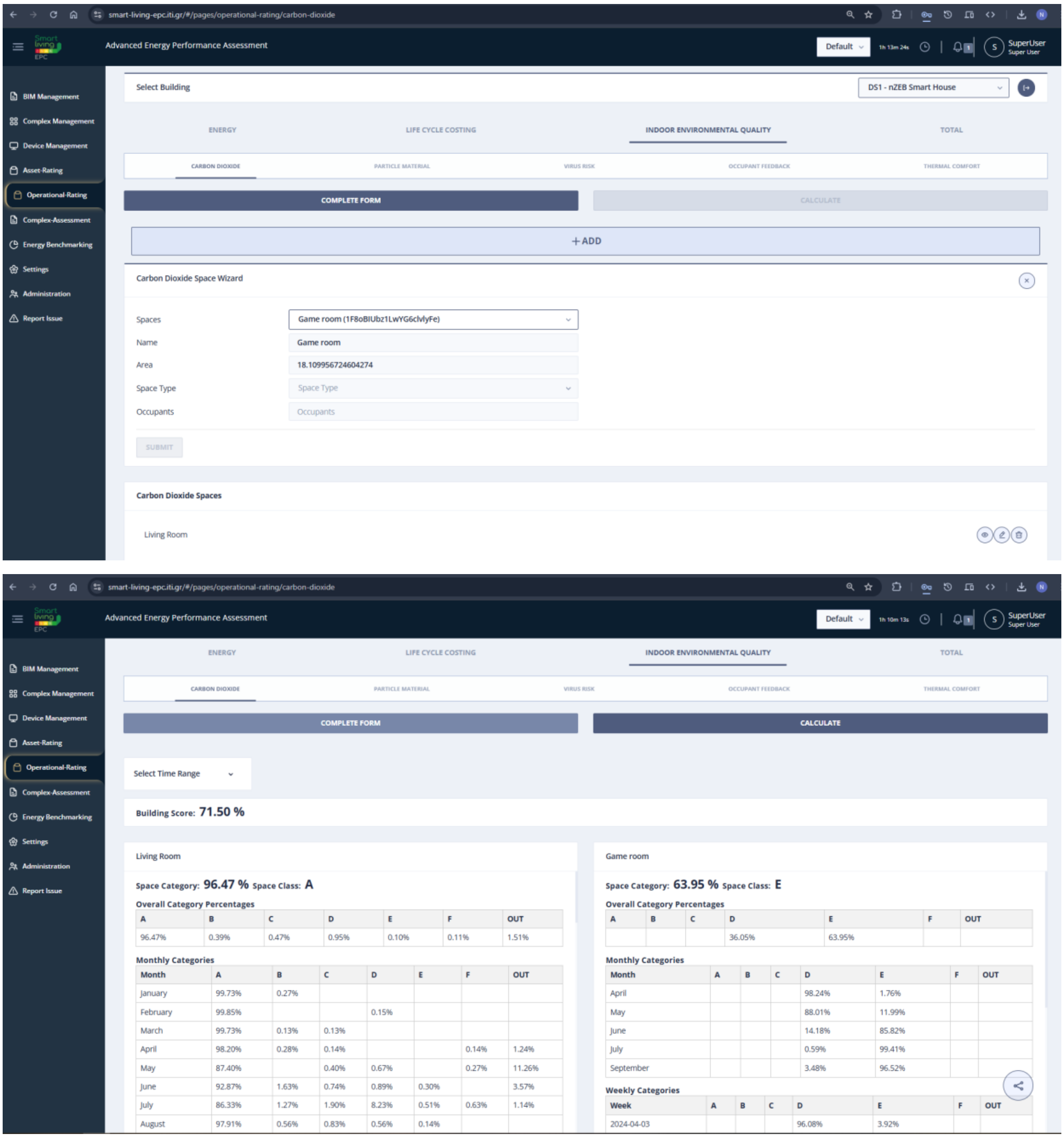


Figure 34. SmartLivingEPC Web Platform. Asset Rating Dashboard. IEQ. IAQ-Carbon Dioxide.

The calculation of the **indoor air quality** related to **particle material** (PM) is performed per building space, which includes a sensing device that measures PM concentration. Since no further setup other than PM concentration measurements is required, the assessment is performed automatically when the user visits the page. The results are displayed per assessed space and in total (Figure 35), while the user can also change the assessment period, as previously described.

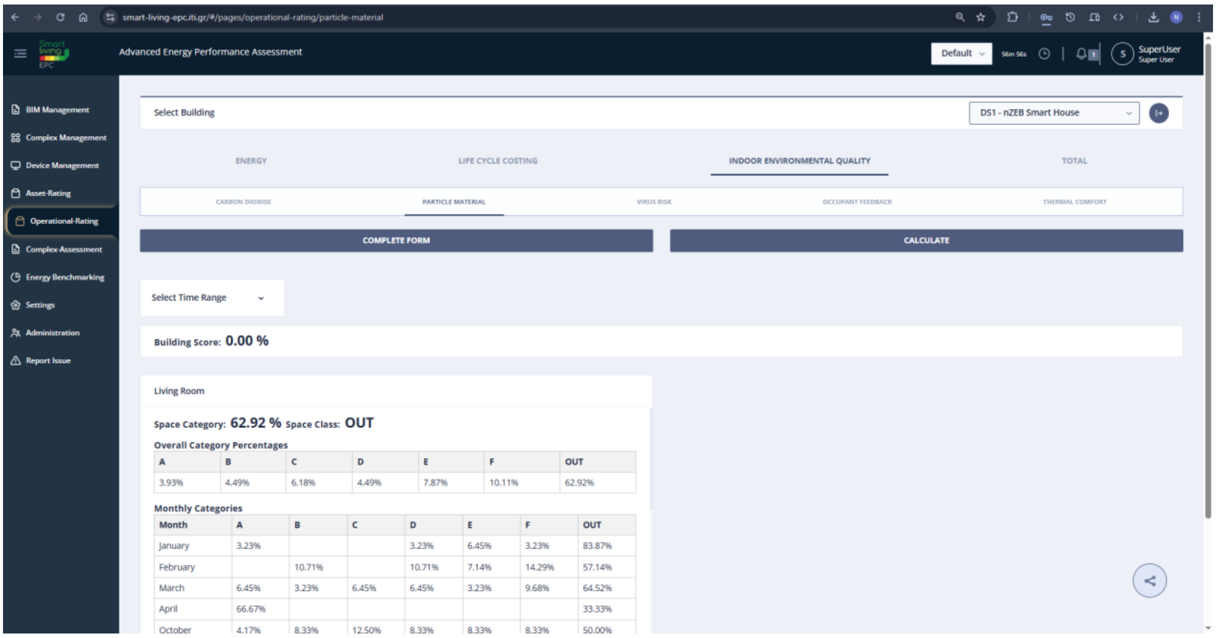
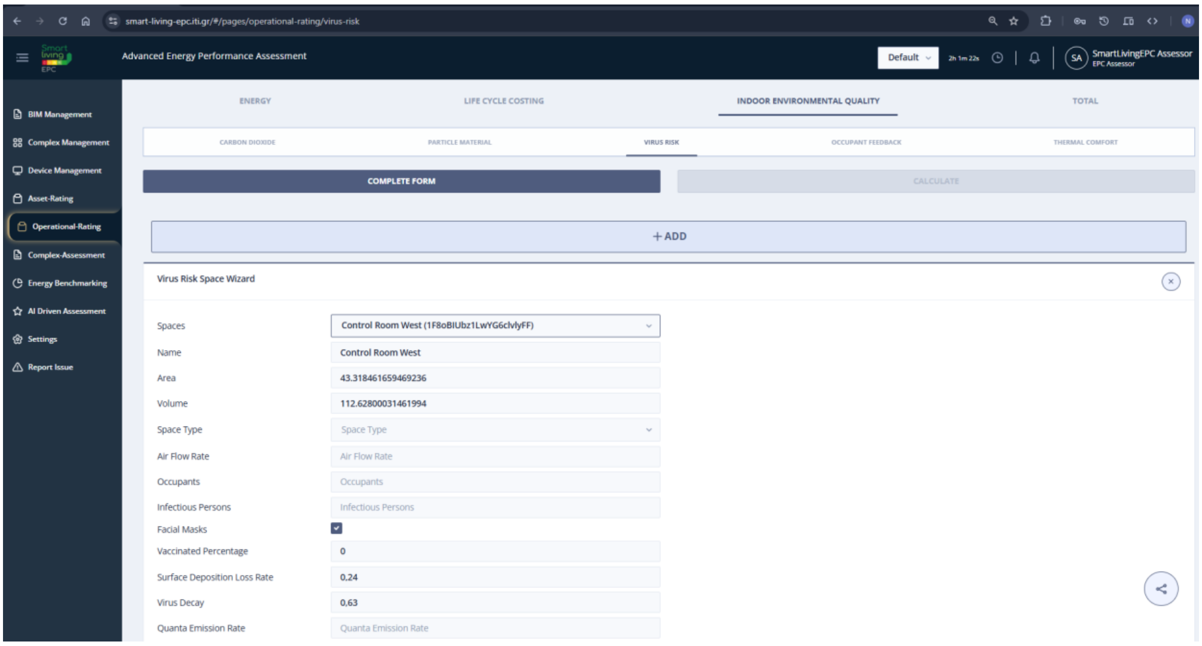


Figure 35. SmartLivingEPC Web Platform. Asset Rating Dashboard. IEQ. IAQ-Particle Material. Indicators.

The calculation of the indoor air quality related to virus risk is performed per building space. The first step requires the setup of each assessment space (Figure 36 top) where the user can select any space that has not already been set up. The area and the volume of each space is calculated automatically, while the user needs to enter additional details related to the virus risk assessment.

Upon completion of the setup process for the required spaces, the calculated results (per assessed space and in total) are presented to the user, as in the bottom of Figure 36.



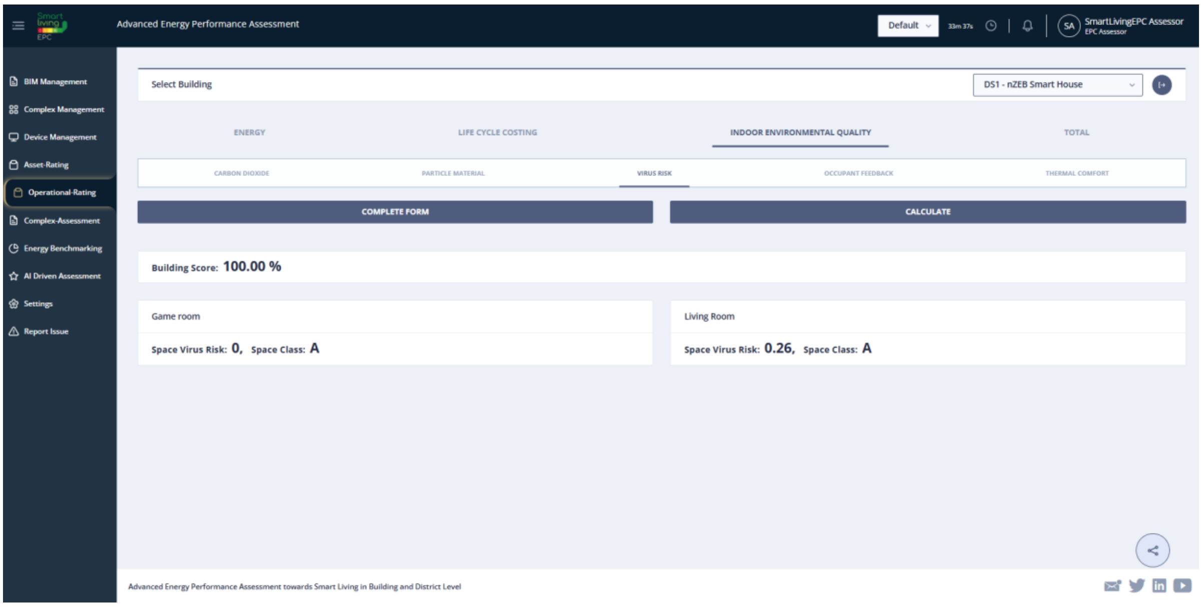
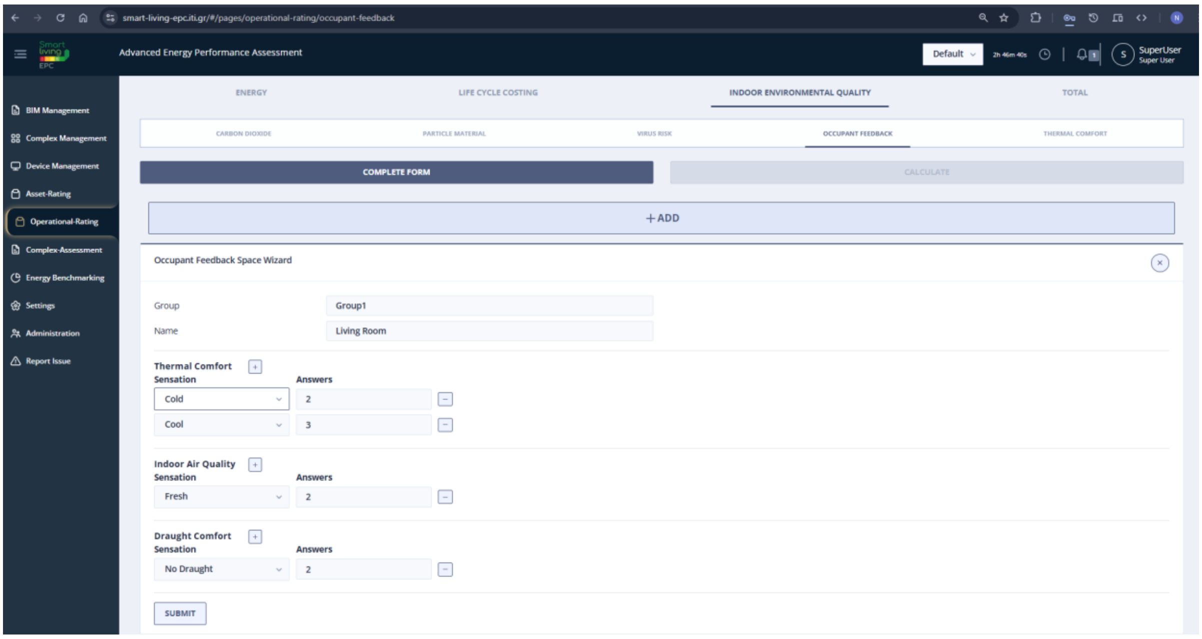


Figure 36. SmartLivingEPC Web Platform. Asset Rating Dashboard. IEQ. IAQ-Virus Risk Assessment.

The calculation of the indoor environmental quality as perceived by the **occupants' feedback** is performed per building space and occupant group. The first step requires the setup of each assessment space (Figure 37 top) where the user can select any available building space and assign a specific name to the group of people that occupy it. The same space can be set up again with a different group. Following next, the occupants' perception of thermal comfort, indoor air quality and draught, as determined by appropriate questionnaires, can be inserted.

Upon completion of the setup process for the required spaces, the calculated results (per assessed space, per occupant group and in total) are presented to the user, as in the bottom of Figure 37.



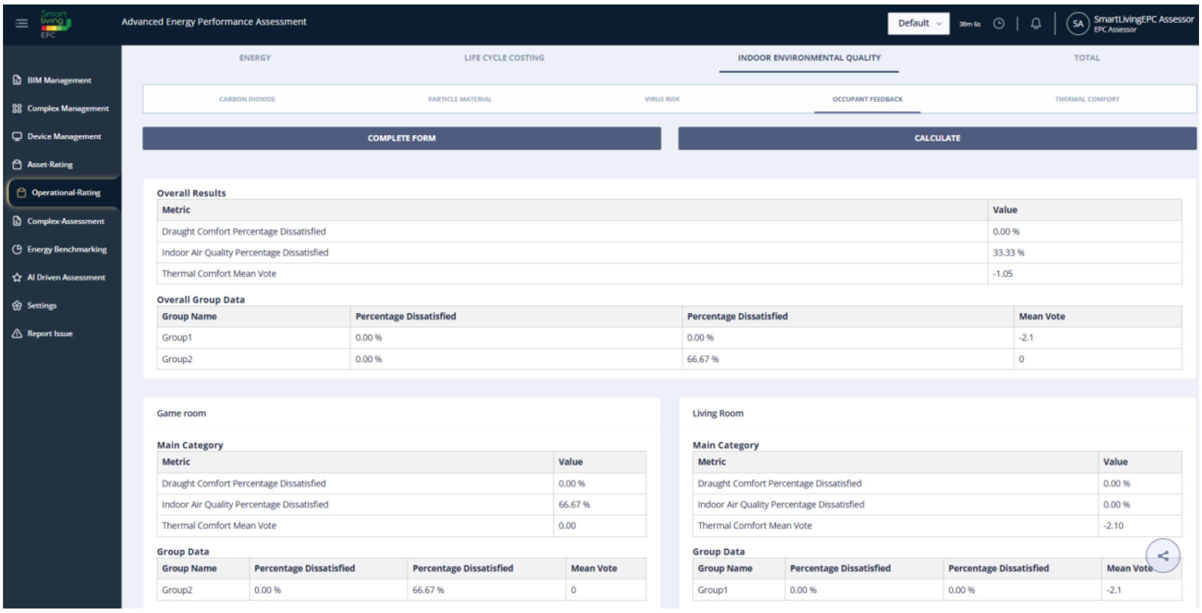
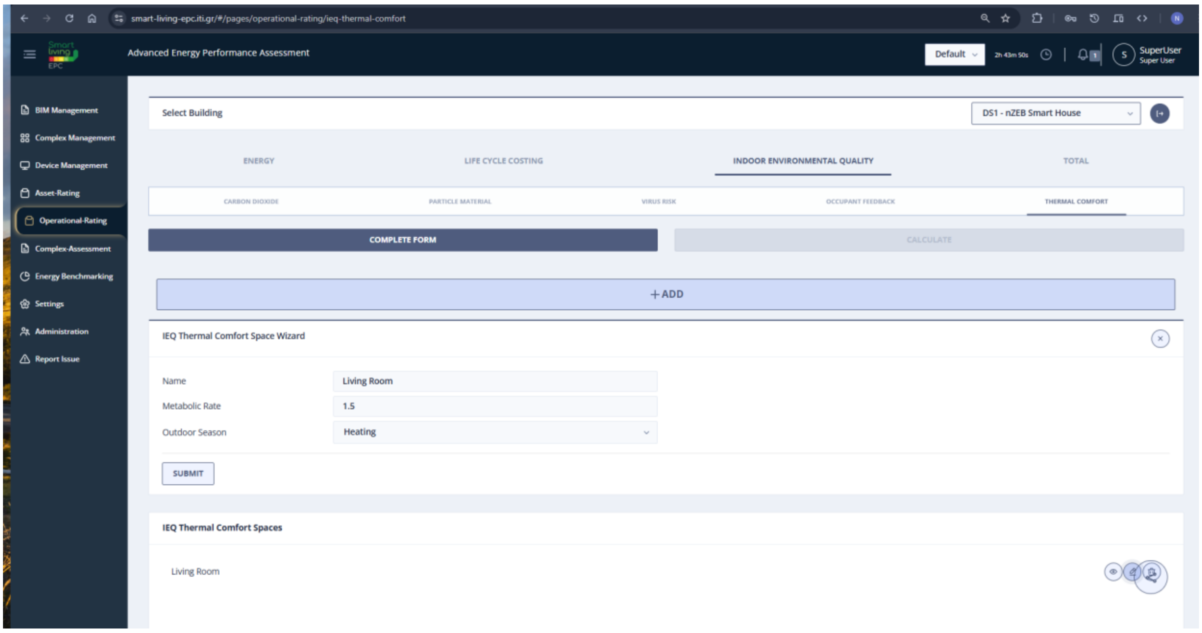


Figure 37. SmartLivingEPC Web Platform. Asset Rating Dashboard. IEQ. IAQ-Occupants' feedback.

The calculation of the building's **thermal comfort** is performed per building space, which includes a sensing device that measures indoor air temperature. The first step requires the setup of each assessment space (**Figure 38** top), where only appropriate spaces (i.e. those that have an air temperature sensor installed within them) are provided to the user for selection. The user needs to enter the metabolic rate of the occupants and the outdoor season for the calculation.

The results are displayed per assessed space and in total (**Figure 38** bottom), while the user can also change the assessment period, as previously described.



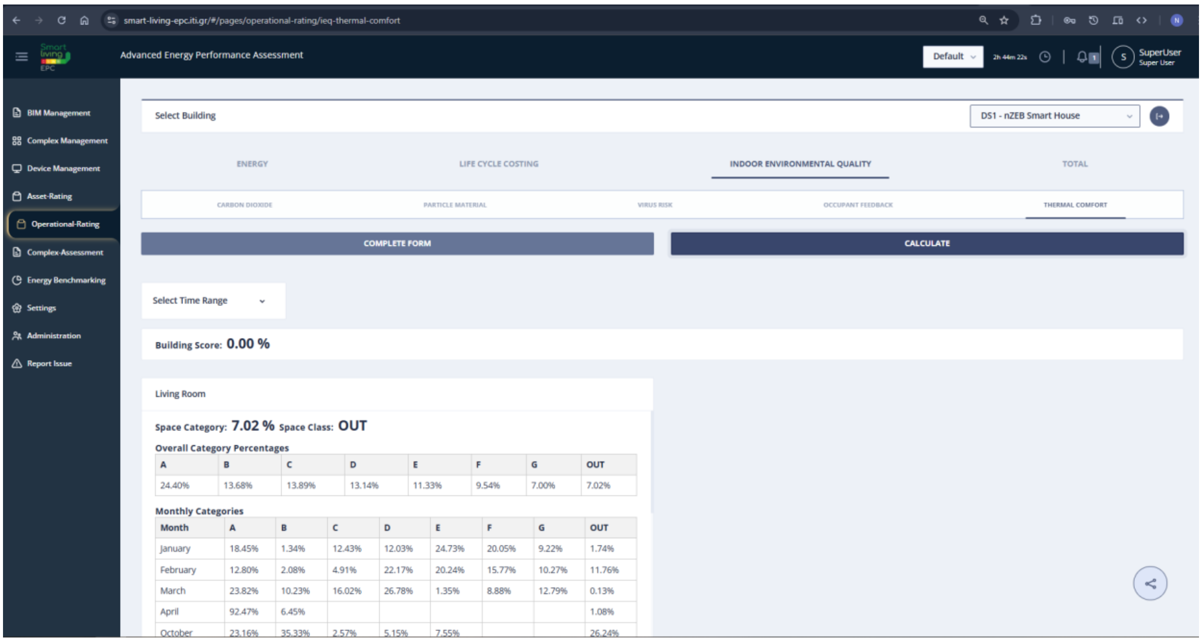


Figure 38. SmartLivingEPC Web Platform. Asset Rating Dashboard. IEQ. Thermal Comfort.

The **overall asset assessment** is performed through the total tab. There, the results from each component are leveraged to obtain the overall operational assessment indicator and rating (**Figure 39**).

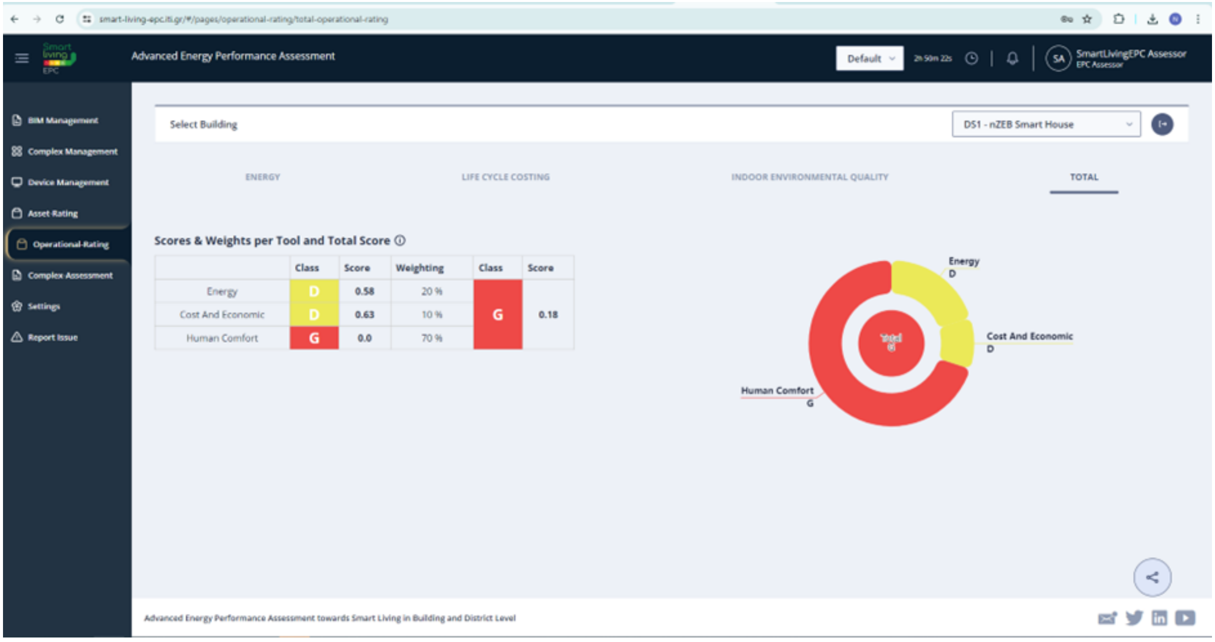


Figure 39. SmartLivingEPC Web Platform. Operational Rating Dashboard. Overall Indicators.

3.2.6 Complex Assessment

The asset and operational assessments at the complex level are performed in the **Complex Assessment** dashboard.

The asset rating tab provides user input forms for each complex asset-rating indicators group (**Figure 40** top), allowing the assessor to enter the necessary information. In several fields, an "Autofill" button can be used for automatic retrieval of the information that has been extracted from the BIM files of the consisting building units.

Following the completion of the setup, the user can execute the tool and view the indicator results (**Figure 40** bottom).

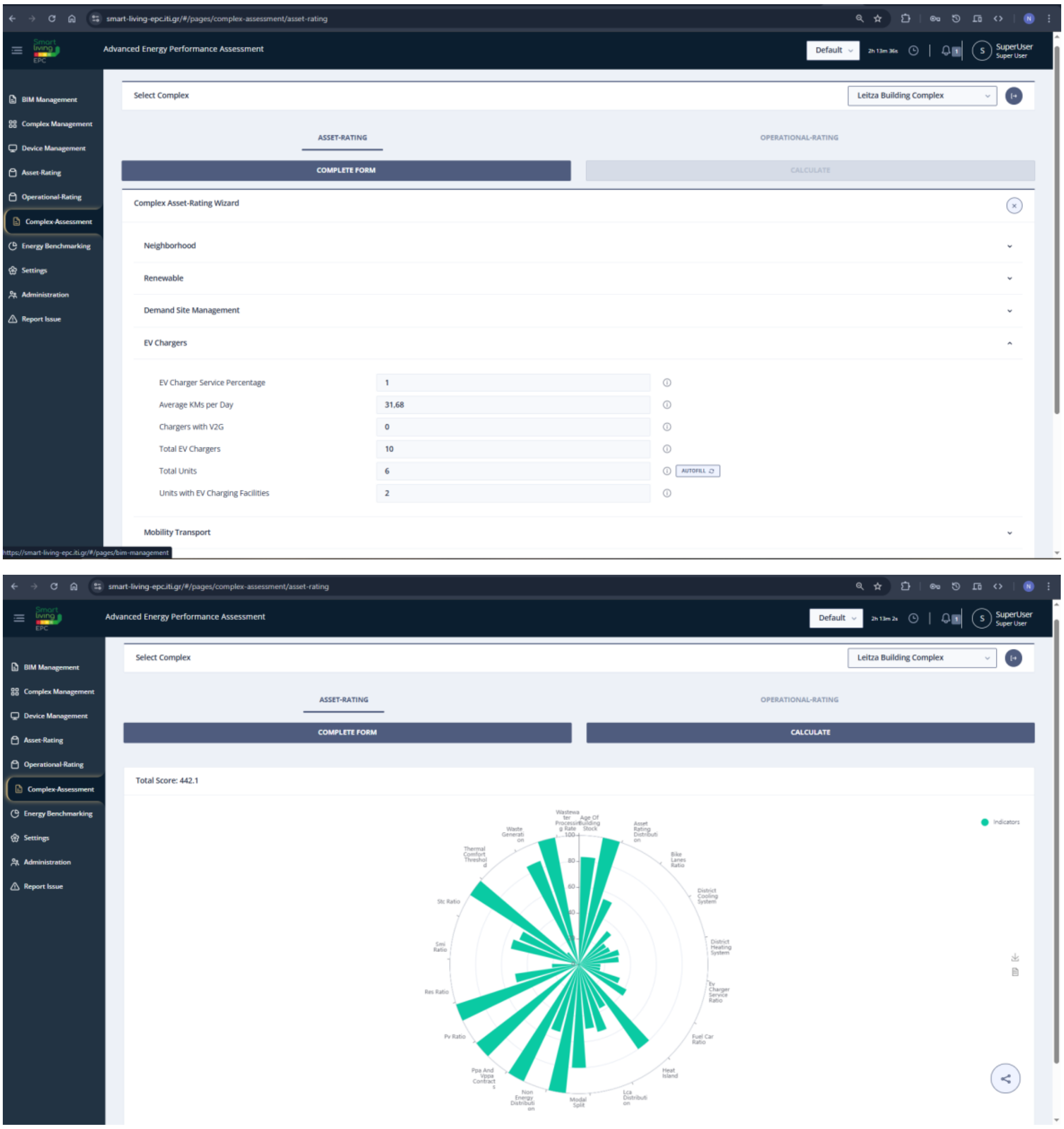


Figure 40. SmartLivingEPC Web Platform. Complex Assessment. Asset Rating.

The **operational rating** tab provides user input forms for each complex operational-rating indicators group (**Figure 41** top), allowing the assessor to enter the necessary information. Fields that depend on complex-level measured data are automatically computed based on the actual data collected by the IoT devices that were set up as described in section 3.2.3. Following the completion of the setup, the user can execute the tool and view the indicator results (**Figure 41** top).

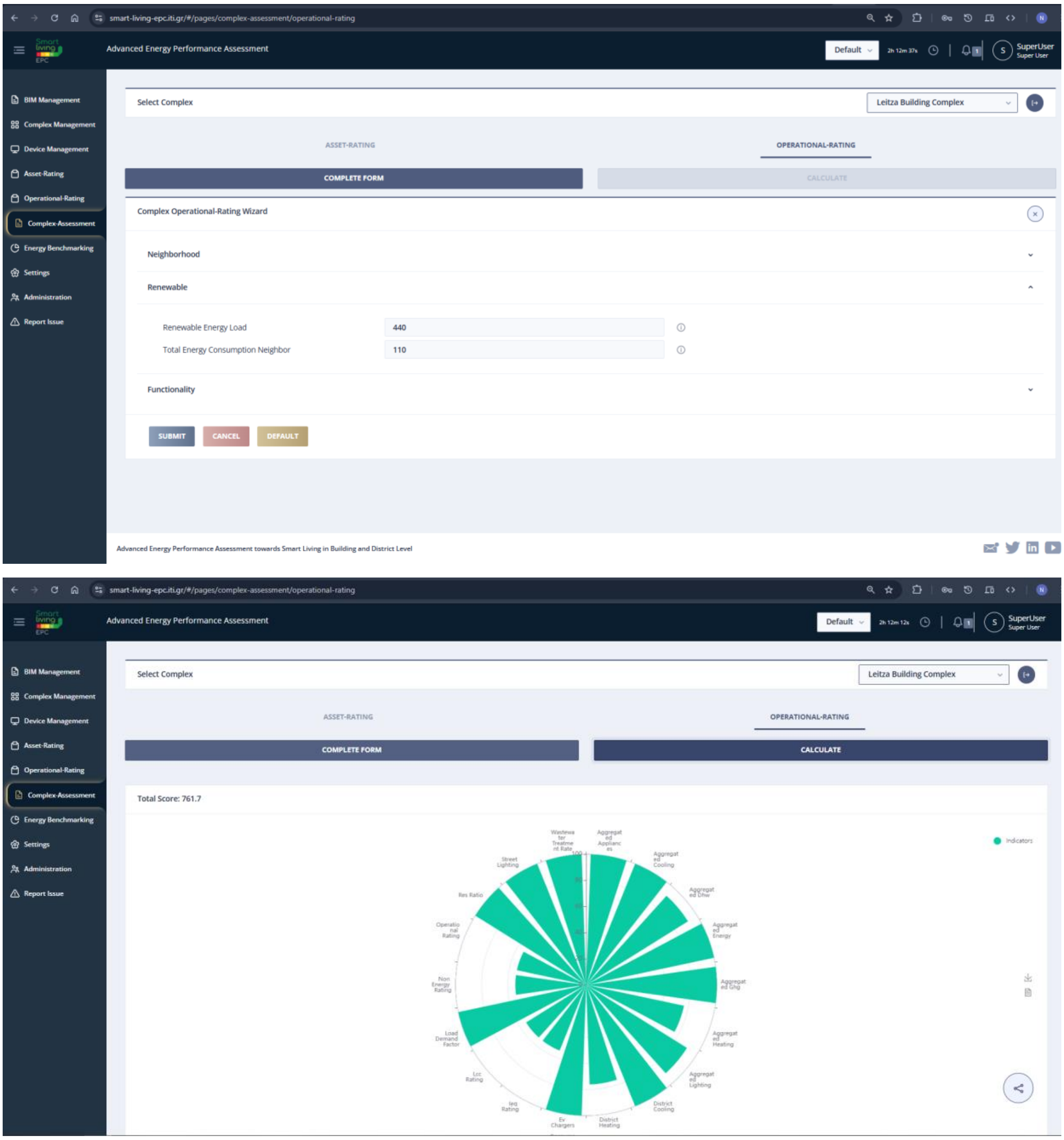
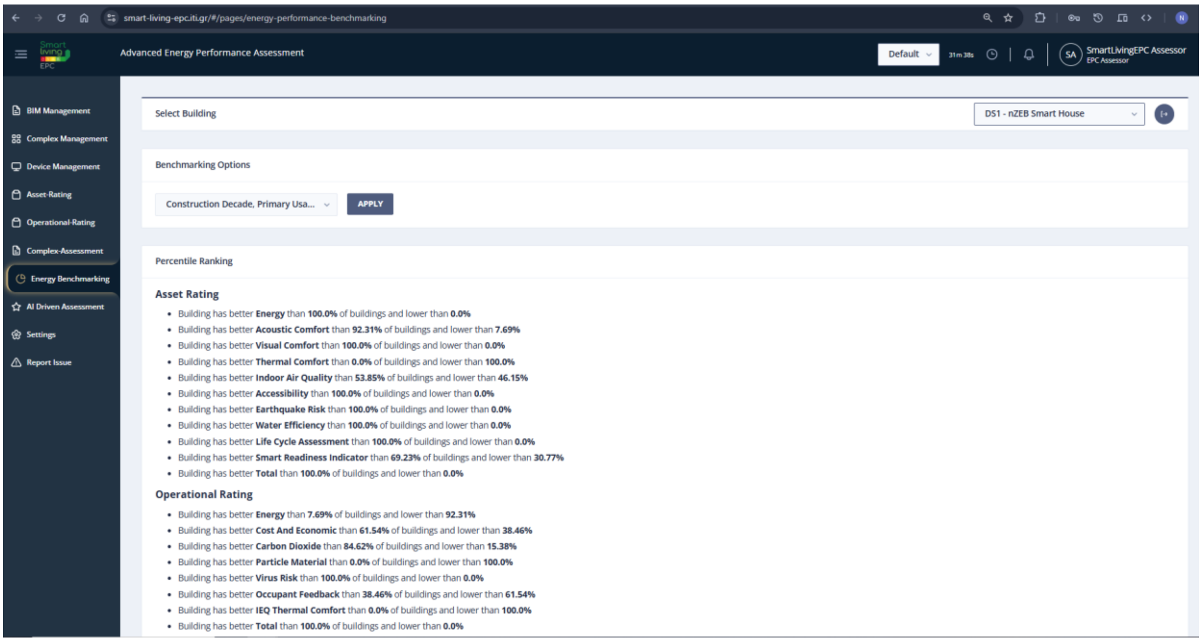


Figure 41. SmartLivingEPC Web Platform. Complex Assessment. Operational Rating.

3.2.7 Energy Benchmarking

In this tab, the selected building is benchmarked against buildings with similar characteristics. The user can select several options that determine the dataset that will be used for the benchmarking process. These include the construction decade, the primary usage, the European region, the country and the building area.

Figure 42 demonstrate the benchmarking results. The first part includes the percentile ranking of the building, which gives an overview of its performance per indicator in asset and operational rating.


smart-living-epc.iti.gr/#/pages/energy-performance-benchmarking
Advanced Energy Performance Assessment
Default
SmartLivingEPC Assessor
EPC Assessor
BIM Management
Complex Management
Device Management
Asset-Rating
Operational-Rating
Complex-Assessment
Energy Benchmarking
AI Driven Assessment
Settings
Report Issue
Select Building
DS1 - nZEB Smart House
Benchmarking Options
Construction Decade, Primary Usa...
APPLY
Percentile Ranking
Asset Rating
Building has better Energy than 100.0% of buildings and lower than 0.0%
Building has better Acoustic Comfort than 92.31% of buildings and lower than 7.69%
Building has better Visual Comfort than 100.0% of buildings and lower than 0.0%
Building has better Thermal Comfort than 0.0% of buildings and lower than 100.0%
Building has better Indoor Air Quality than 53.85% of buildings and lower than 46.15%
Building has better Accessibility than 100.0% of buildings and lower than 0.0%
Building has better Earthquake Risk than 100.0% of buildings and lower than 0.0%
Building has better Water Efficiency than 100.0% of buildings and lower than 0.0%
Building has better Life Cycle Assessment than 100.0% of buildings and lower than 0.0%
Building has better Smart Readiness Indicator than 69.23% of buildings and lower than 30.77%
Building has better Total than 100.0% of buildings and lower than 0.0%
Operational Rating
Building has better Energy than 7.69% of buildings and lower than 92.31%
Building has better Cost And Economic than 61.54% of buildings and lower than 38.46%
Building has better Carbon Dioxide than 84.62% of buildings and lower than 15.38%
Building has better Particle Material than 0.0% of buildings and lower than 100.0%
Building has better Virus Risk than 100.0% of buildings and lower than 0.0%
Building has better Occupant Feedback than 38.46% of buildings and lower than 61.54%
Building has better IEQ Thermal Comfort than 0.0% of buildings and lower than 100.0%
Building has better Total than 100.0% of buildings and lower than 0.0%


BIM Management
Complex Management
Device Management
Asset-Rating
Operational-Rating
Complex-Assessment
Energy Benchmarking
AI Driven Assessment
Settings
Report Issue
Operational Rating Median Comparison
Asset Rating Top Performer

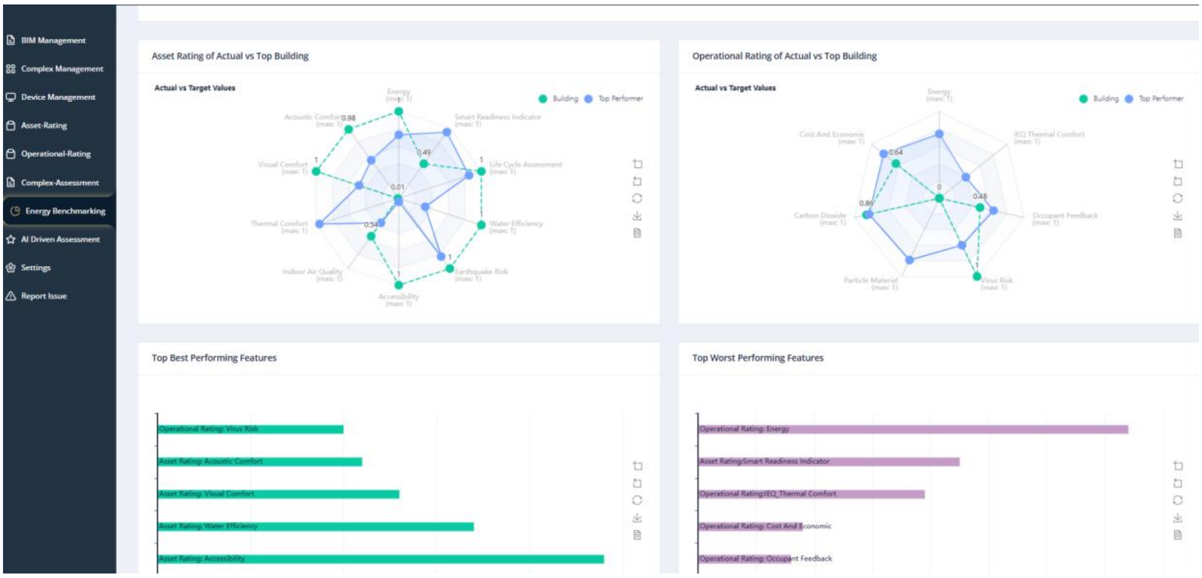


Figure 42. SmartLivingEPC Web Platform. Energy Benchmarking.

3.2.8 AI Driven Assessment

This page provides access to external AI engines services.

In the **Maintenance Anomalies Detection** tab, the user can select different metrics from several IoT monitoring devices as well as a custom data time range on which the anomalies detection will be applied. Following next, the user can add several rules for each device, indicating the detection level and occurrence time threshold (**Figure 43** top).

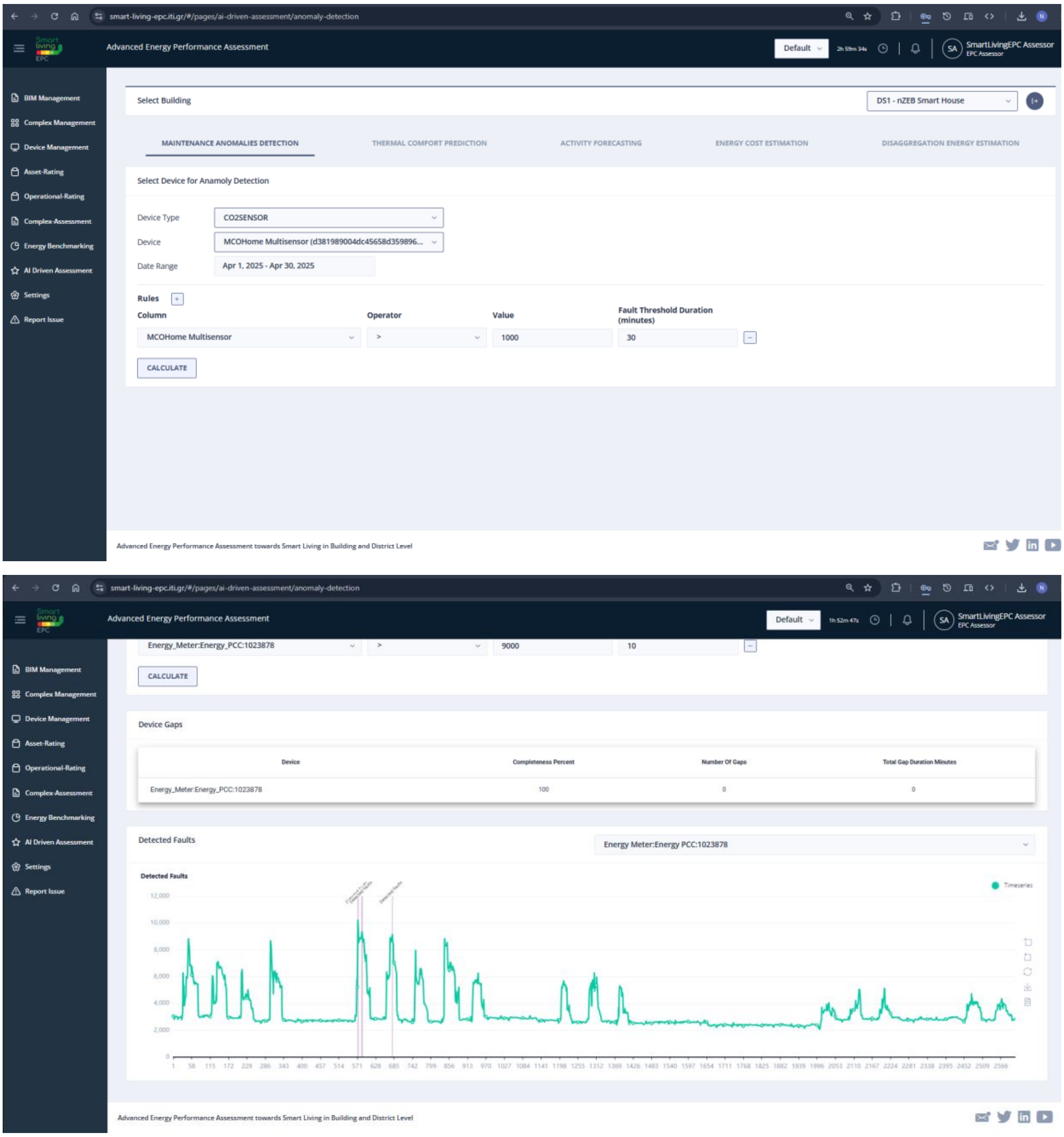


Figure 43. SmartLivingEPC Web Platform. AI-Driven Assessment. Maintenance Anomalies Detection

Upon successful execution, the results are displayed in a graph per assessed device as in (**Figure 43** bottom).

In the **Thermal Comfort Prediction** tab, the user can initially select any building space that has a temperature-humidity sensor installed within (**Figure 44** top). The date range, which dictates the amount of data fed to the engines, should also be defined, along with several static parameters (air velocity, occupant metabolic rate and clothing insulation level. The user may also select the comfort evaluation contexts, i.e. PMV/PPD, Adaptive Thermal Comfort and ML-based Thermal Comfort Vote.

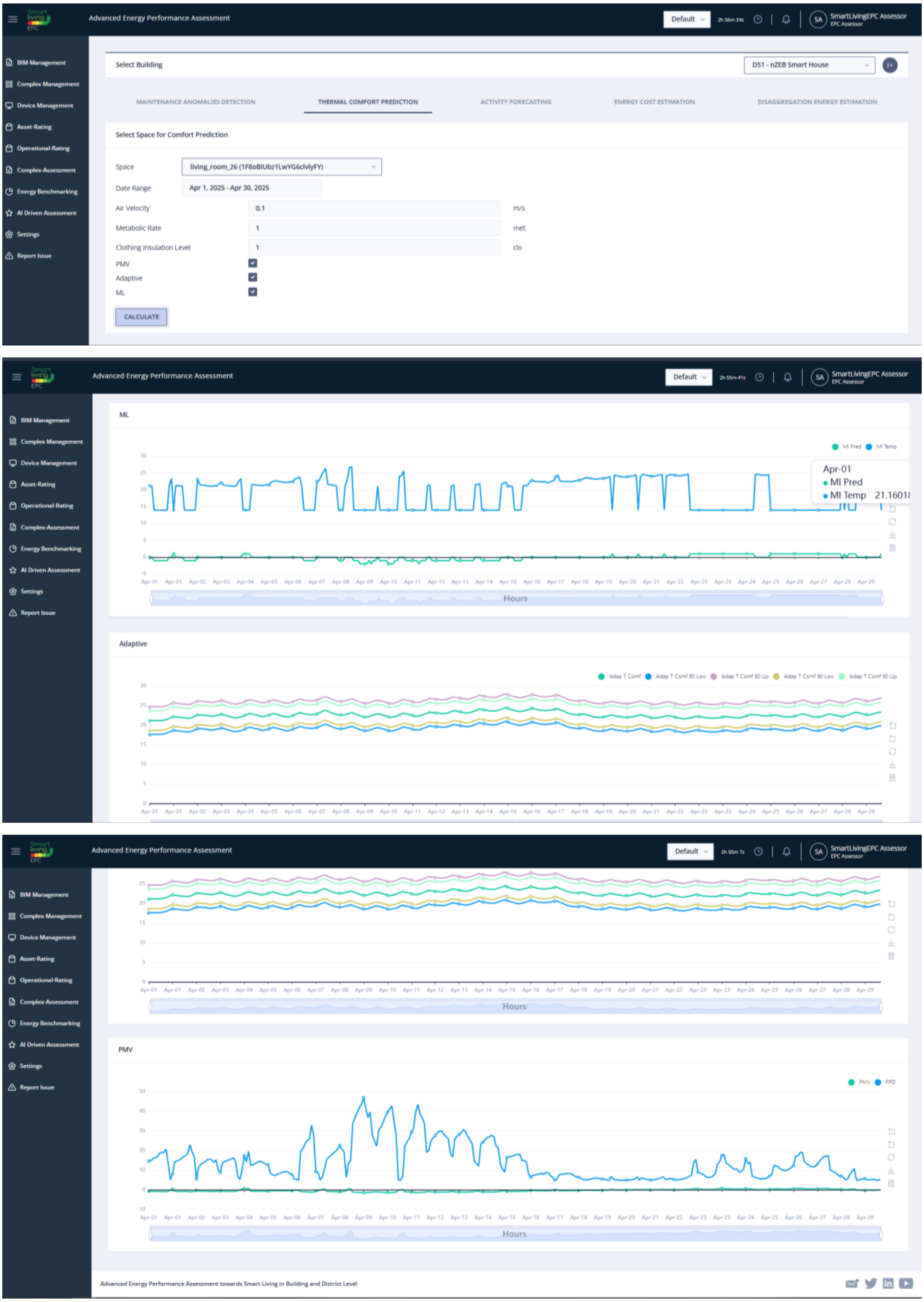


Figure 44. SmartLivingEPC Web Platform. AI-Driven Assessment. Thermal Comfort Prediction

Upon successful execution, the results are displayed as in **Figure 44** centre and bottom.

In the **Activity Forecasting** tab, the user can select any metric type and the corresponding building monitoring devices that support it. Following next, a date range should be provided, which will define the amount of data fed to the engine. Upon successful execution, the results (a daily profile of the input data) are available to the user. The setup process and the results of the activity forecasting engine are demonstrated in **Figure 45**.

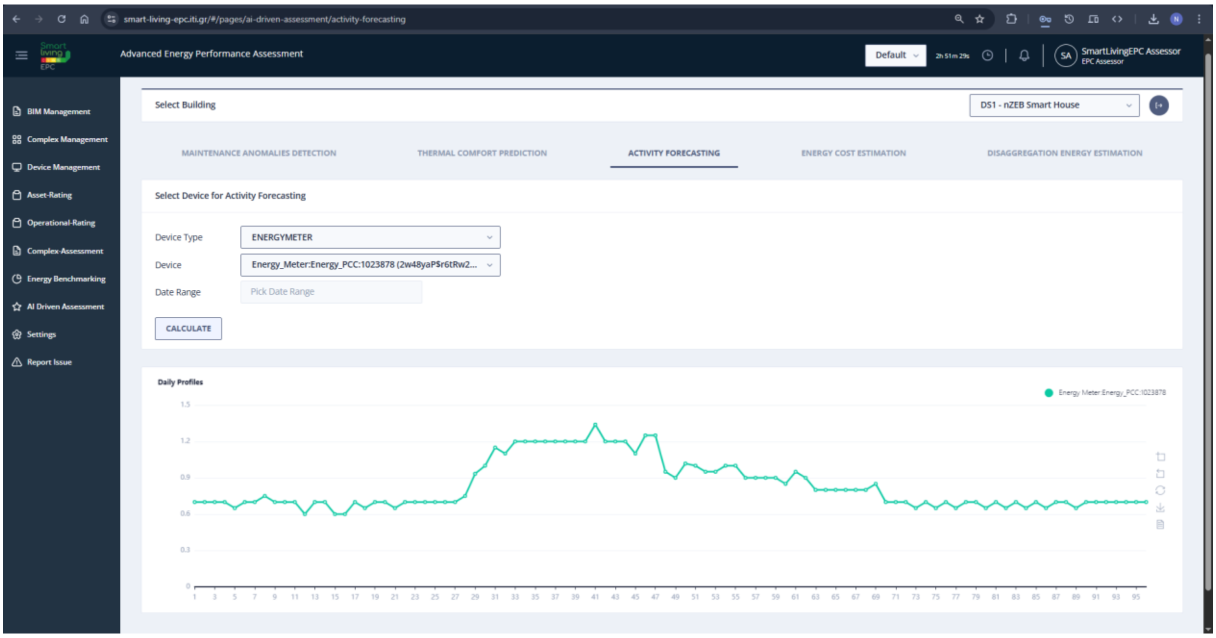


Figure 45. SmartLivingEPC Web Platform. AI-Driven Assessment. Activity Forecasting

In the **Disaggregation Energy Estimation** tab (**Figure 46**), the user can select the desired energy vectors (electricity or gas and electricity), the building type and the input type of measurements (monthly/cumulative). Following next, a date range should be provided, which will define the amount of data fed to the engine, automatically retrieved from the corresponding energy and/or gas meters. Upon successful execution, the disaggregation load results are available to the user.

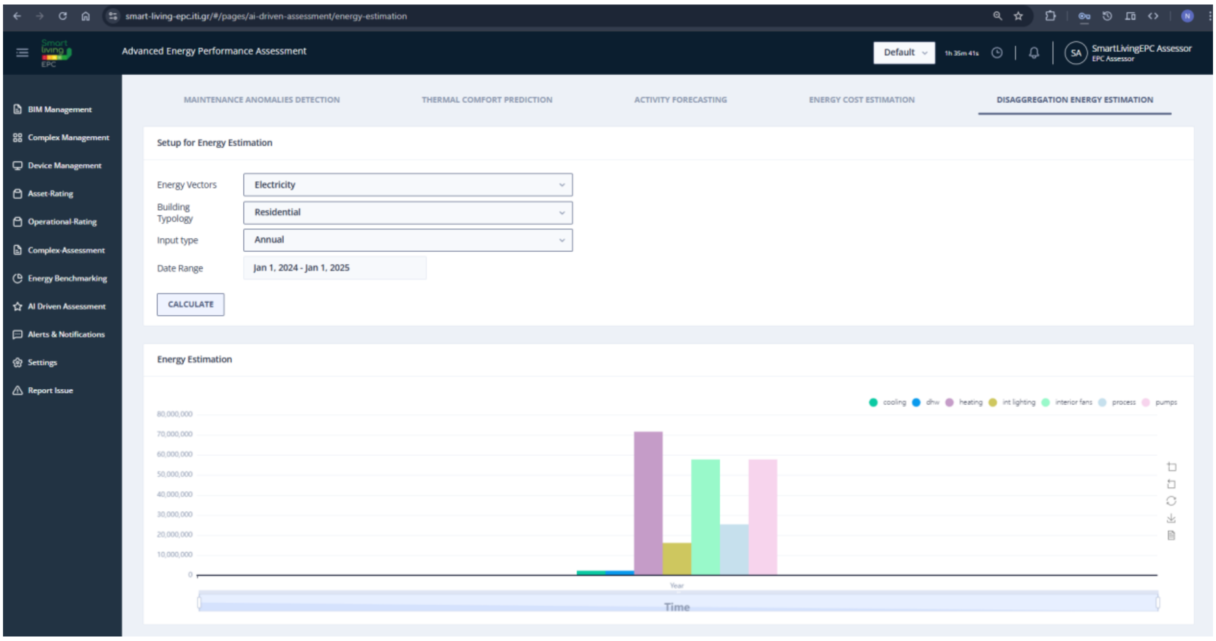


Figure 46. SmartLivingEPC Web Platform. AI-Driven Assessment. Dissagregation Energy Estimation

In the **Energy Cost Estimation** tab, the results of the Energy Cost Estimation engine. There is no requirement for manual user inputs, as the energy consumption, the energy pricing and the carbon emission factors are provided automatically based on the available building measurements and its country. The results of the assessment are visualized in **Figure 47**.

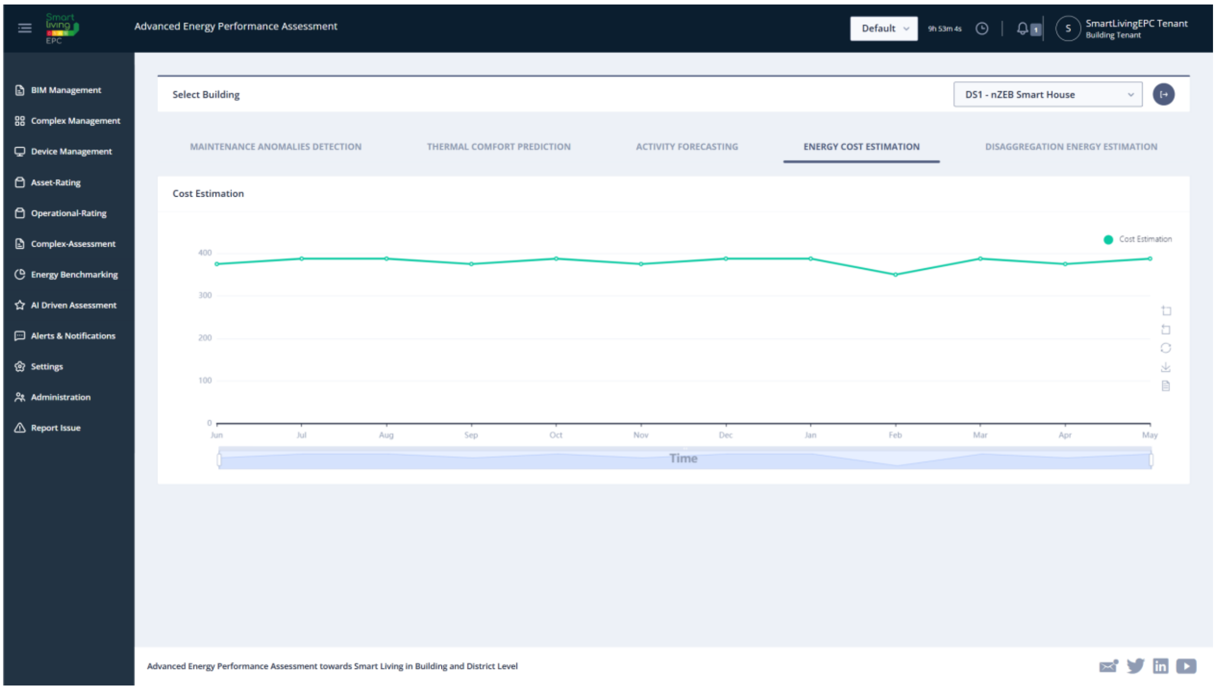


Figure 47. SmartLivingEPC Web Platform. AI-Driven Assessment. Energy Cost Estimation.

3.2.9 Alerts & Notifications

The Alerts and Notifications page displays essential information resulting from the operations or calculations performed by various tools on the platform. This information is organized into four levels of severity: Info, Suggestion, Warning, and Error, as shown in **Figure 48**.

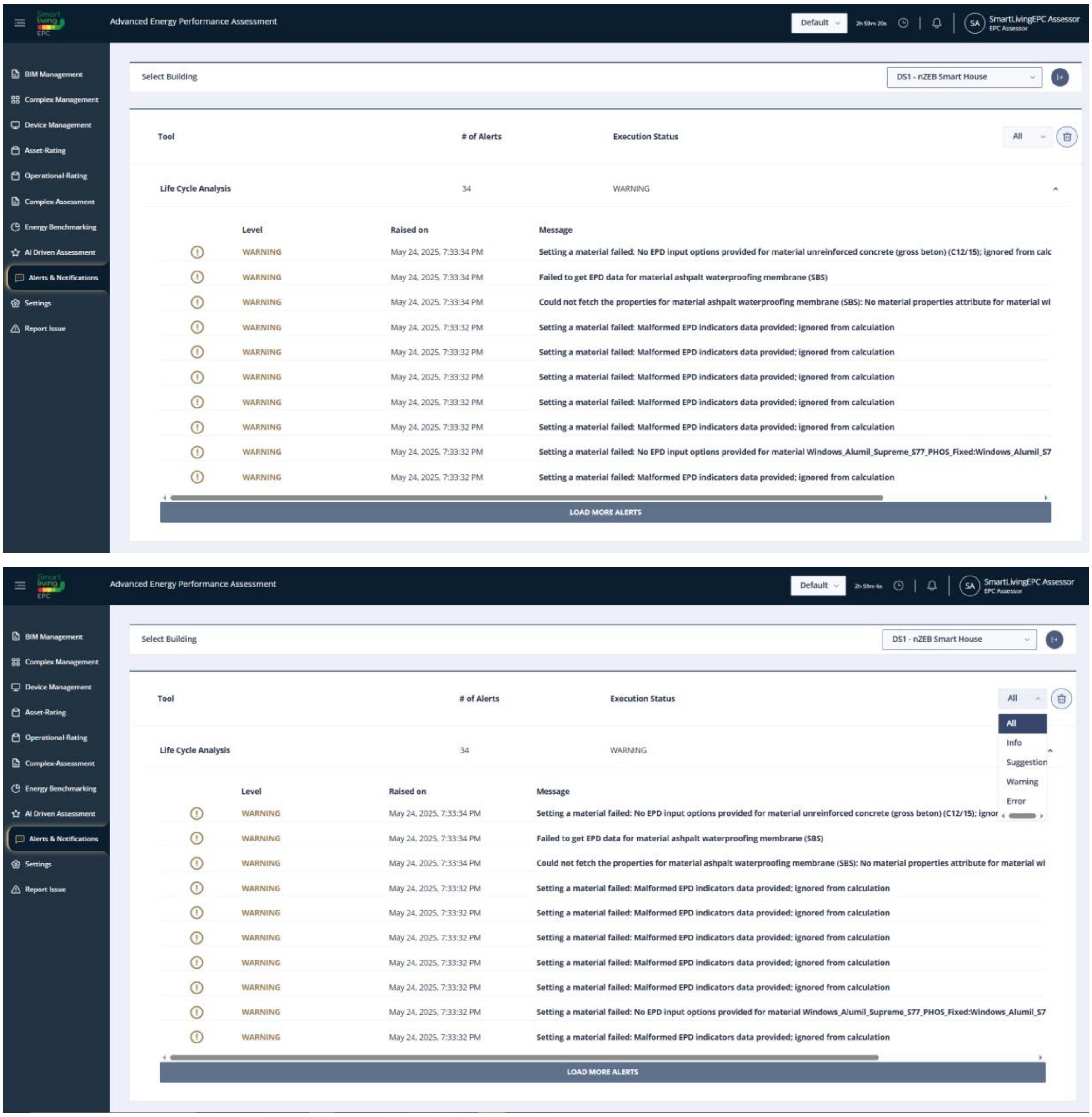


Figure 48. SmartLivingEPC Web Platform. Alerts and Notifications

The various alerts are presented according to the related calculation tool. The user can open each separate row with the arrow on the right and view in chronological order the list of alerts and notifications

3.2.10 Settings

The settings management are performed in the **Settings** dashboard. This page enables manual building/complex data management (Figure 49). The user can upload building data measurements in a predefined .csv format, which are then mapped to the devices that have been registered in the Device Management pages. Additionally, all the building unit/complex data that have been stored in the CIEM database can be downloaded directly as CSV or JSON files.

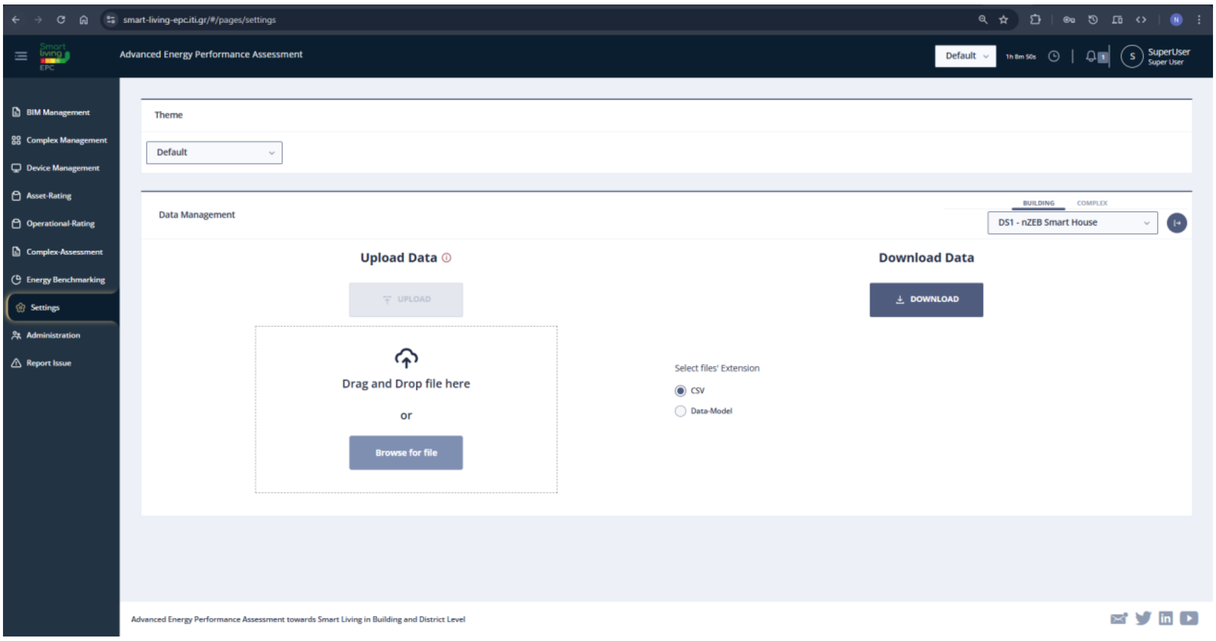


Figure 49. SmartLivingEPC Web Platform. Settings

3.2.11 Report Issue

The reporting of issues is performed in the **Report Issue** dashboard (Figure 50). Therein users may report an issue through a user-friendly form with the following fields: title of the issue, category (e.g., bug or suggestion for improvement), thorough description, and label corresponding with element of the Web Platform. Upon submission, a dedicated issue is created in the Gitlab version control system that hosts the SmartLivingEPC Web Platform software stack, which will be addressed by the responsible parties.

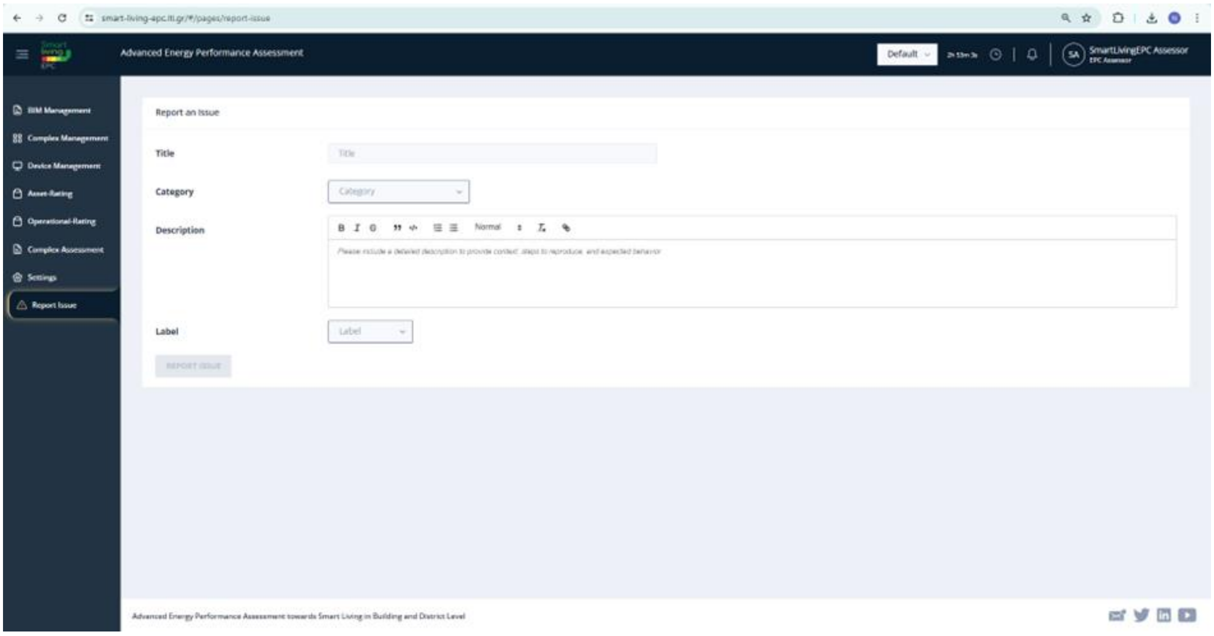


Figure 50. SmartLivingEPC Web Platform. Report Issue Dashboard. Overview.

3.3 User Account Management

From the **profile page** (Figure 51), accessible through the main top right corner of the main dashboard (Figure 10), the user is able to modify the credentials, the user name displayed, and upload a profile picture. The unique user identification number may be obtained as well. The unique user identification number, when shared with other users, enables collaboration (i.e., viewing and/or editing) rights on projects which have not been uploaded by the user.

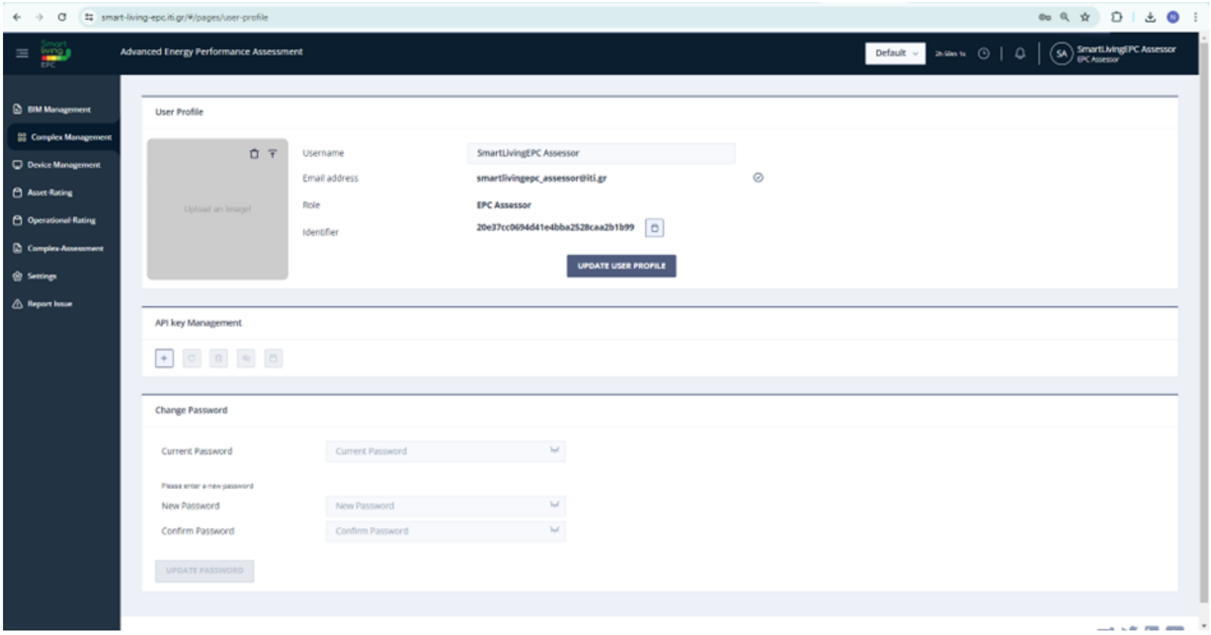


Figure 51. SmartLivingEPC Web Platform. Profile Page.

Additionally, from the **profile page** a personalised API key can be obtained for accessing various platform services directly.

3.3.1 Changing Password

In case of having forgotten the password, there is a “Forgot Password” button (Figure 8). After providing the user email, a recovery link is sent enabling password reset.

3.4 Troubleshooting & FAQs

Table 80 and Table 81 depict the SmartLivingEPC Web Platform most common issues and suggested fixes, and the error messages respectively.

Table 80. SmartLivingEPC Web Platform. Common Issues and Fixes

Issue	Description	Suggested Fix
UI not loading	The application interface does not render or remains stuck on the loading screen.	Ensure a stable internet connection. Try clearing browser cache and cookies. If the problem persists, reload the page or use a different browser.
Login failure	Users are unable to log into their accounts.	Confirm credentials are correct. If forgotten, use the “Forgot Password” option. Check if the account is locked or deactivated.

Backend timeout	Actions such as saving data or fetching records result in timeout errors.	Check network connectivity. Retry the action after a few minutes. If the issue continues, report the problem via the issue reporting form.
Missing data	Records or user data appear incomplete or missing.	Try refreshing the data or clearing filters. If the issue persists, check user permissions. Contact support for data recovery assistance.

Table 81. SmartLivingEPC Web Platform. Error Messages

Error Code	Message	Description / Meaning	Suggested Resolution
400	Missing fields!	Required fields in the request are empty or not provided.	Ensure all mandatory form fields are filled before submission.
400	Invalid or Unsecure Filename!	The filename is either unsafe or does not meet validation rules.	Rename the file to remove special characters or unsupported patterns.
400	Passwords do not match!	Password and confirmation fields differ.	Re-enter matching passwords.
400	Please check your login details and try again!	Incorrect email or password.	Double-check credentials. Reset the password if needed.
401	Token has expired!	Authentication token is no longer valid.	Login again to get a new token.
403	The account is not approved / verified / has been disabled!	User account state prevents access.	Contact support or wait for account approval.
403	Users are not eligible to perform this action!	The user lacks required permissions.	Check role-based access. Contact admin for permission updates.
404	No BIM(s) or IFC found!	Data requested is not available.	Ensure the resource was uploaded or try reloading.
500	Failed to store/download IFC or Data Model!	Internal server or file processing error.	Try again later. If it persists, contact support.

If the issue is not resolved with the above steps, please use the in-app Issue Reporting feature:
1. Navigate to the Report Issue page in the UI.
2. Provide a brief description, steps to reproduce.
3. Click on Report an Issue.
4. You will receive a follow-up via your registered email.

3.5 Security and Privacy

The SmartLivingEPC Web Platform incorporates robust data protection measures to ensure the confidentiality, integrity, and availability of user data. This section outlines both the technical safeguards in place and the responsibilities of platform users to uphold security and privacy standards.

3.5.1 Platform Data Protection Measures

To protect all data processed through the platform, the following security practices are implemented:

- **End-to-End Encryption**: All data exchanged between the client and server is secured using Transport Layer Security (TLS) version 1.2 or higher.

- **Access Management**: Role-based access control (RBAC) is enforced to ensure that users can only access the data and functionalities relevant to their assigned roles.
- **Audit Logging**: Key user actions are logged systematically and monitored for irregular or potentially malicious activity.

3.5.2 User Responsibilities

Users also play a critical role in maintaining data security. To support a secure and privacy-respecting environment, all users are expected to:

- Use strong, unique passwords and refrain from sharing their login credentials.
- Always log out after accessing the platform on shared or public devices.
- Promptly report any suspicious behavior or unauthorized access attempts to the system administrator.
- Avoid storing sensitive personal data in unstructured or free-text input fields unless strictly necessary.

3.5.3 GDPR Compliance

The SmartLivingEPC Web Platform is fully compliant with the General Data Protection Regulation (GDPR). Key compliance principles include:

- **Data Minimization**: The platform collects and retains only the data required to deliver its core functionalities and services.
- **User Rights**: In accordance with GDPR, all users have the right to access, rectify, export, or request the deletion of their personal data by contacting the designated data controller.

4 Validation Workshops

4.1 Introduction

This section deals with the description of the approaches for gathering feedback from stakeholders, concerning potential improvements of the tool. The step-by-step plan for workshops is described below:

1. Internal Validation and Testing with Consortium Partners
2. Pilot Ecosystem Validation
3. Public Validation Workshop
4. Documentation and Refinement of Workshop Procedures
5. Full Roll-out of Workshops in All Pilot Ecosystems
6. Consolidation and Analysis of Feedback
7. Next Steps for Tool Improvement and Final Validation

The subsequent sections deal with the explanation of each of the step's objectives, activities, and expected outcomes. The results of the implementation of each of the steps will be documented in D6.4.

Beyond the validation workshops described in this section, several dissemination activities have been performed aiming to share with external stakeholders the details about the SmartLivingEPC Framework, in an exercise towards transparency, enabling peer-review and feedback. They are described in detail in WP7 deliverables. A non-exhaustive list is provided below for illustrative purposes: Table 82 for scientific publications and Table 83 for webinars and public workshops.

Table 82. Examples of scientific publications related to the SmartLivingEPC Framework

Title	Publication Date	Published in	Related component of the SmartLivingEPC Framework
Post-COVID ventilation design: Infection risk-based target ventilation rates and point source ventilation effectiveness	7 July 2023	Energy and Buildings	Operational Rating Engine, IEQ component
Innovative SRI Evaluation Through BIM: Developing a Unique Rule-Checking Methodology Utilizing the IFC Schema	26 June 2024	Proceedings of the 9th International Conference on Smart and Sustainable Technologies – SpliTech 2024	Asset Rating Engine, SRI component
Building renovation Roadmapping: an automated methodology framework for energy efficiency improvement and sustainable renovation planning	10 September 2024	International Journal of Sustainable Energy	SmartLivingEPC Web Platform

Table 83. Webinars and public workshops related to the SmartLivingEPC Framework

Title	Activity Date	Format	Attendees	Related component of the SmartLivingEPC Framework
Internal SmartLivingEPC Web Platform Webinar	10/10/2024	In-person, during the 5th Consortium Meeting in Dublin (Ireland)	The consortium partners.	The whole platform, except for the AI-Driven engines.

4.2 Internal Validation and Testing

The first step seeks to ensure that the SmartLivingEPC components function as intended, identifying any immediate issues before engaging external stakeholders. The different components of the SmartLivingEPC framework are depicted in Figure 52.

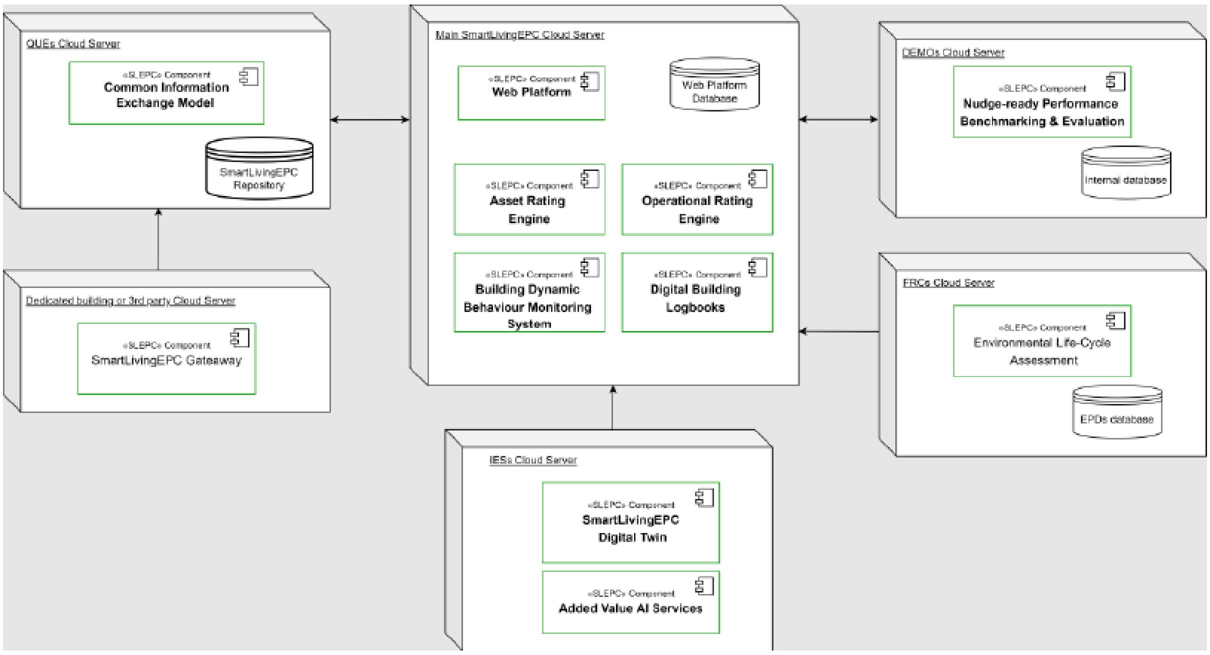


Figure 52. SmartLivingEPC architecture deployment view. Source: D5.1

The procedure is to first **identify key testing stakeholders**: define who within each partner organisation will be responsible for initial testing. Next, to **set testing criteria**: establish a list of core functions and usability criteria that the tool should meet. Thirdly, to define a **testing timeline** for internal testing, with dedicated slots for feedback collection. Lastly, establishing a **feedback collection method**: decide on a standard form (e.g., survey or structured report) to collect feedback from each partner to keep data consistent. The expected outcome ought to be a basic validation report on tool usability and functionality to guide adjustments before the first external pilot workshop.

The actions within this step have been conducted in the framework of WP5 and WP6 activities and mainly performed by the methodology and component development teams. Some of the internal validation and testing of the components, according to the functional requirements defined in D1.3, are documented in D5.1. For example, the *Thermal Comfort Engine* and *Anomaly Detection Engine*– part of the added-value AI tools developed in Task 5.1; the *Evaluation Engine*, *Benchmarking Engine*, and *Recommendation Engine* components– part of the nudge-ready performance benchmarking and evaluation tools developed in Task 5.2 have been asynchronously tested by the development teams with CERTH's Smart House pilot successfully meeting the testing and validation criteria. In addition to the formal evaluation activities, the engines were continuously tested during their development as part of an iterative and integrated process. These tests were conducted in close alignment with the developments in WP2 and WP3 to ensure functional compatibility and performance. ILastly, the SmartLivingEPC Web Platform has implemented a report issue page, which enables any user to submit a report to the platform management team. Thus, creating a dedicated issue in the Gitlab version control system that hosts the platform software stack, to be addressed by the responsible person.

A next iteration of this first step is announced in D5.1 to be documented in D5.2. It shall include testing and validation of the remaining added-value AI tools engines: *Activity Inference Engine*, *Disaggregation Engine*, *Simulation tool*, and *Cost Estimation Engine*. Furthermore, it shall explore the testing and validation using pilot's data stored in the CIEM, rather than pilot data provided offline.

4.3 Pilot Ecosystem Validation

The second step aims to test the tool in a real-world setting within the pilot ecosystems. The procedure is to first **establish validation protocols**; this is the validation methodology for the Use Cases – defined in D6.4 and the survey to gather feedback from stakeholders from the pilot ecosystems– developed by UDEUSTO in T6.5. Next, to **validate the use cases within the pilot ecosystems** following the methodology defined by T6.4, which is reproduced below.

1. The methodology developer is notified by the developing team at CERTH when the SmartLivingEPC Web Platform is ready for testing each specific Use Case with the pilots.
2. If the Use Case requires input data or validation, the partner responsible for each Use Case shall contact the pilot manager(s) and request the necessary information, which shall be provided in a timely manner.
3. The partner responsible for each Use Case shall conduct the validation and notify the pilot manager(s) for further validation of the results. This process will be documented in D6.4.

According to the pilot analysis included in D1.3, demonstration ecosystems #1 – nZEB Smart House, #2 – Limassol Main Building at Frederick University, and #3 – Ehituse Mäemaja at Tallin University of Technology are considered well-equipped pilot buildings. This is confirmed by D6.2, which indicates that such pilots are well-equipped with IEQ sensors and energy meters, including advanced features such as presence sensors for room occupancy. While operational data is already being delivered to their IoT platforms, additional outdoor CO_2 and PM2.5 sensors will be installed shortly. The compatibility of their existing API with CIEM is established, though the need for an additional interface for pilot #1 will be assessed at a later stage. Pilot buildings corresponding to the Leitza municipality monitor renewable energy generation and electricity use but lack indoor environmental quality (IEQ) monitoring. Planned upgrades include IEQ sensors, a weather station, and additional energy meters. The communication infrastructure will use LORA protocols, with IoT devices and platforms integrated with CIEM from the start.

Various User Acceptance Tests (UATs) are described in D5.1 covering on functionality, usability and compatibility. Templates are provided for each, and the pre-requisite of having a device with active internet connection to perform them is indicated. They are to be used as master guide of the testing scenarios and workflows of the *SmartLivingEPC Web Platform*.

4.4 Public Validation Workshop

The third step is the Public Validation Workshop, which aimed at validation of the SmartLivingEPC Web Platform by practicing experts. To that end, REHVA devised the structure of the workshop for demonstration, testing, and structured feedback collection. The structure was the following.

- **Introduction to the Project** by **Paris Fokaides**, Scientific Coordinator of SmartLivingEPC, setting the scene for how this innovative platform fits into the broader sustainable buildings landscape.
- **Live Demonstration** of the **SmartLivingEPC Web Platform** by **Nikos Katsaros**, the Lead Developer of the solution — see the platform's capabilities in action!
- **Interactive Validation & Feedback Session** led by **Leandro Martín Ferrón** and **Aitziber Mugarra Elorriaga**, where your insights as users will directly contribute to refining the platform's features and usability.
- **Moderation** by **Pablo Carnero**, Technical EU Project Officer at REHVA, ensuring an engaging, informative, and dynamic discussion.

The event was designed as an online, freely accessible webinar (Figure 53). The public validation workshop was first advertised during the project's final event on May 6th and extensively promoted through the communication and dissemination channels.

The stakeholder feedback was carried out by UDEUSTO, and it is documented in D6.4.

The complete recording of the webinar can be found on the project's YouTube channel[5].

Figure 53. Public Validation Workshop banner.

4.5 Documentation and Refinement of Workshop Procedures

After the Public Validation Workshop with external professionals, the objective is to document key learnings and procedural adjustments to create a replicable and effective format for other ecosystems. First, an **analysis of the feedback from the workshop** ought to be conducted, compiling findings from the pilot ecosystems to identify procedural strengths and improvement areas. Next, **revise workshops materials and methods**: update any workshop guidelines, participant materials, and feedback forms based on initial insights. Last, **standardise workshop format**: develop a harmonised format for subsequent workshops including common feedback methods. The expected outcome is a clear, replicable workshop format that aligns all pilot ecosystems on consistent feedback gathering and demonstration processes.

The documentation and refinement of workshop procedures will be described in D6.4.

4.6 Full Roll-Out of Workshops in pilot ecosystems

The goal is to expand the workshops to collect wide-ranging stakeholder input. To this end, each project coordinator will organise a workshop targeting local stakeholders. The workshop's objective is to demonstrate the SmartLivingEPC Web Platform and to gather feedback using the survey to gather feedback from pilot stakeholders– developed by UDEUSTO in T6.5.

Firstly, **assign workshop leads in each ecosystem**: identify responsible partners in each ecosystem to coordinate workshops. Second, **align workshops scheduling**: set a coordinated schedule for workshops across ecosystems, accounting for potential regional variations. Lastly, **support workshop implementation**: provide additional support materials and guidance from initial lessons learned. The expected outcome is the completion of workshops across all pilot ecosystems, gathering comprehensive feedback on tool performance and usability.

[5] Access the recording of the Public Validation Workshop here: https://youtu.be/uEge0qwDN5c?si=XP0JQ7RXbMXXRRhe

4.7 Consolidation and Analysis of Feedback

The aim is to aggregate and analyse feedback from all workshops to determine tool improvements. It begins with the **compilation of all feedback data** in a standardised format. Then, **conduct a comparative analysis**: look for common issues or areas of improvement highlighted by different ecosystems. Last, **prioritise tool enhancements**: based on feedback, identify high-priority areas for tool enhancement and usability improvements.

The compilation of feedback data and analysis feedback will be documented in D6.4.

4.8 Next Steps for Tool Improvement and Final Validation

The objective is to make necessary adjustments to the tool and validate its improvements. First, **assign development priorities**: coordinate with development teams to address prioritised tool modifications. Second, **plan a final validation phase**: outline a follow-up testing and validation phase post-improvements, involving a smaller sample of stakeholders from each ecosystem. The expected outcome is a final, validated version of the tool ready for widespread use.

5 Conclusions

The successful completion of this deliverable marks a key milestone for the SmartLivingEPC project. It provides a clear and comprehensive overview of the scheme’s theoretical foundations, assessment procedures, and implementation tools. The inclusion of a detailed user manual and validation strategy enhances the practical applicability of the framework. Overall, the deliverable demonstrates significant progress and readiness for the next phases of development and testing.

6 References

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ANNEX A: EPB Standard modules

In this section, the EPB standards' modular structure and references from ISO/TR 52010-2 is reproduced.

Table 84. EPB Standards modules and submodules. Reproduced from [2].

Main area	Overarching		Building as such		Technical Building Systems										
					Description	Heating	Cooling	Ventilation	Humidification	Dehumidification	Domestic Hot Water	Lighting	Building automation & control	Electricity production
Module	**M1**		**M2**			**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**
Submodule	**Desc.**	**Std**	**Desc.**	**Std**		**Std**								
1	General	ISO 52000-1 ISO/TR 52000-2	General	-	General	EN 15316-1	EN 16798-9 CEN/TR 16798-4	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-4	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-4	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-	EN 15316-1	EN 15193-1	EN 15232-1 CEN/TR 15232-2	
2	Common terms and definitions; symbols; units and subscripts	ISO 52000-1 ISO/TR 52000-2	Building Energy Needs	ISO 52016-1 ISO 52017-1 ISO/TR 52016-2	Needs						EN 12831-3	prEN 15193-1		
3	Applications	ISO 52000-1 ISO/TR 52000-2	(Free) Indoor conditions without systems		Maximum load and power	EN 12831-1	ISO 52016-1 ISO/TR 52016-2				EN 12831-3			
4	Ways to Express Energy Performance	ISO 52003-1 ISO 52003-2	Ways to Express Energy Performance	ISO 52018-1 ISO/TR 52018-2	Ways to Express Energy Performance	EN 15316-1	EN 16798-9 CEN/TR 16798-10	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-4	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-4	EN 16798-3 (EN 13779 rev.) CEN/TR 16798-4	EN 15316-1	EN 15193-1 CEN/TR 15193-2	EN 15232-1 CEN/TR 15232-2	

5	Building Functions and Building Boundaries	ISO 52000-1 ISO/TR 52000-2	Heat Transfer by Transmission	ISO 13789 ISO 13370 ISO 6946 ISO 10211 ISO 14683 ISO/TR 52019-2 ISO 10077-1 ISO 10077-2 ISO 12631	Emission & control	EN 15316-2 EN 1500 CEN/TR 15500 EN 12098-1 CEN/TR 12098-1 EN 12098-3 CEN/TR 12098-3 EN 12098-5 CEN/TR 12098-5	15316-2 EN 15500 CEN/TR 15500	EN 16798-7CEN/TR 16798-8 EN 15500 CEN/TR 15500	EN 16798-5-1 EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798-6-2	EN 16798-5-1 EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798-6-2			EN 15232-1 CEN/TR 15232	
6	Building Occupancy and Operating Conditions	EN 16798-1 CEN/TR 16798-2 [ISO 17772-1, ISO/TR 17772-2 (to be published)]	Heat Transfer by Infiltration and Ventilation	ISO 13789	Distribution & control	EN 15316-3 EN 12098-1 CEN/TR 12098-1 EN 12098-3 CEN/TR 12098-3 EN 12098-5 CEN/TR 12098-5	EN 15316-3	EN 16798-5-1 EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798-6-2			EN 15316-3		EN 15232-1 CEN/TR 15232-2	
7	Aggregation of Energy Services and Energy Carriers	ISO 52000-1 ISO/TR 52000-2	Internal Heat Gains	See M1-6	Storage & control	EN 15316-5 EN 12098-1 CEN/TR 12098-1 EN 12098-3 CEN/TR 12098-3 EN 12098-5 CEN/TR 12098-5	EN 16798-15 CEN/TR 16798-16				EN 15316-5 EN 15316-4-3		EN 15232-1 CEN/TR 15232-2	

8	Building Zoning	ISO 52000-1 ISO/TR 52000-2	Solar Heat Gains	ISO 52022-3ISO 52022-1ISO/TR 52022-2	Generation & control	EN 12098-1 CEN/TR 12098-1 EN 12098-3 CEN/TR 12098-3 EN 12098-5 CEN/TR 12098-5 EN 15316-4-1 EN 15316-4-2 EN 15316-4-3 EN 15316-4-4 EN 15316-4-5 EN 15316-4-6 EN 15316-4-8	EN 16798-13CEN/TR 16798-14 EN 15316-4-2 EN 15316-4-5	EN 16798-5-1 EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798-6-2	EN 16798-5-1 EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798-6-2	EN 16798-5-1 EN 16798-5-2 CEN/TR 16798-6-1 CEN/TR 16798-6-22	EN 15316-4-1 EN 15316-4-2 EN 15316-4-3 EN 15316-4-4 EN 15316-4-5 EN 15316-4-6		EN 15232-1 CEN/TR 15232-2	EN 15316-4-3 EN 15316-4-4 EN 15316-4-5 EN 15316-4-7
9	Calculated Energy Performance	ISO 52000-1 ISO/TR 52000-2	Building Dynamics (thermal mass)	ISO 13786	Load dispatching and operating conditions								EN 15232-1 CEN/TR 15232-2	
10	Measured Energy Performance	ISO 52000-1 ISO/TR 52000-2	Measured Energy Performance		Measured Energy Performance	EN 15378-3					EN 15378-3	EN 15193-1 CEN/TR 15193-2	EN 15232-1 CEN/TR 15232-2	
11	Inspection		Inspection	(existing standards on IR inspection, airtightness, ...)	Inspection	EN 15378-1	EN 16798-17 CEN/TR 16798-18	EN 16798-17 CEN/TR 16798-18	EN 16798-17 CEN/TR 16798-18	EN 16798-17 CEN/TR 16798-18	EN 15378-1	EN 15193-1 CEN/TR 15193-2	WI 00247092	
12	Ways to Express Indoor Comfort	EN 16798-1CEN/TR 16798-2(ISO 17772-1, ISO/TR 17772-2)			BMS								WI 00247093	
13	External Environment Conditions	ISO 52010-1ISO/TR 52010-2												
14	Economic Calculation	EN 15459-1												

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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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