D2.6 Asset rating calculation methodology of SmartLivingEPC v2

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Asset rating calculation methodology of SmartLivingEPC v1

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	T2.3 Environmental life-cycle assessment and integration to SmartLivingEPC
	T2.4 Technical audits and inspections integration to SmartLivingEPC
	T2.5 Building complex assessment asset methodology
	T2.6 SmartLivingEPC asset rating calculation methodology
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v	Author	Date	Brief Description
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4	**Catalin Lungu**	**12.06.204**	**Final version for submission**

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Table of Contents

List of Figures

List of Tables

List of Acronyms, Abbreviations and other Terms used in the document

Term	Description
BIM	Building Information Modelling
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
HVAC	Heating, Ventilation, Air Conditioning
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
LCA	Life Cycle Analysis
PEP	Primary energy planning
PMV	Predicted Mean Vote
PPD	Percentage of Persons Dissatisfied
SRI	Smart Readiness Indicator
TBS	Technical Building Systems
WHO	World Health Organization
RER	Renewable Energy Ratio

The terms and definitions outlined above reflect those used in standardization. ISO and CEN maintain terminological databases at the following addresses:

1. ISO online browsing platform: available at https://www.iso.org/obp
2. CEN and European standardization available at https://www.cencenelec.eu/

Executive Summary

The goal of the SmartLivingEPC project is to combine multiple indicators into a SLEPC (smart energy performance certificate). This certificate will enhance information on both designed and actual performance in terms of energy efficiency and sustainability by using digital tools and Building Information Modeling (BIM) to record vital data of a building's structure and systems.
Among the SmartLivingEPC's primary features are:

- a novel certification technique
- a thorough assessment of the energy performance, sustainability, smartness, and technical system conditions
- Synergies with sustainability instruments in order to support a life cycle approach, incorporating particular sustainability indicators from the Level(s) scheme
- Compatibility with Digital Building Logbooks

Moreover, the separate neighborhood-scale rating scheme represents a novel approach to energy certification at the neighborhood level by analyzing building-to-building interactions, local microclimate, and urban context, as well as by examining energy infrastructure and services at the building block level, considering elements like street lighting, network services, smart grids, and energy communities. The main features of asset complex EPCs, including prerequisites, inputs for calculations, and outputs, are described in Deliverable D2.4, showing how building interactions at the neighborhood level affect energy performance.

1 Introduction

1.1 General description

Deliverable D2.6 is created within WP2, which focuses on developing methods for assessing building performance. In this work package, D2.6 is important since its goal is to define the asset rating computation method in the context of SmartLivingEPC.

This deliverable primary goal is to conceive a comprehensive and internationally accepted method for assigning asset ratings in conjunction with the proposed weighting mechanism. A variety of performance measures, including energy efficiency, environmental sustainability, smart readiness, and non-energy aspects like indoor environmental quality and accessibility were included in the suggested method. This deliverable is an updated version of the deliverable D2.3.

1.2 Scope and objectives of the deliverable

The SmartLivingEPC project evaluates energy performance of the built environment through a systematic and scientific approach. The current deliverable follows the extent and goals of WP2, accentuating its significance within the wider project structure.

D2.6 is a continuation of D2.3 and offers a thorough description of the SmartLivingEPC framework's asset rating calculation process. It describes the main steps and suppositions involved in calculating energy performance ratings, guaranteeing the incorporation of Building Information Modeling (BIM) for accurate and comprehensive assessments. Wide application is ensured by the methodology's capacity to adapt many building types, including residential and tertiary structures.

The main results is a calculation procedure for **grading assets that includes energy efficiency, non-energy factors, smart readiness, and environmental sustainability at single building or building complex level**.

SLEPC pilot buildings will be used to test the SLEPC rating system, and the outcomes will be recorded to attest to the approach's efficacy as well as provide information on its limits and useful uses. The technique ensures the integration and compliance with European standards by being compatible with current technologies, such as digital building logbooks and BIM tools.

D2.6's goals are as follows:

1. Create a new grading system based on the evaluation of individual building and other intricate factors for the building and neighborhood sizes.
2. Transition from the size of single buildings to the scale of complex of buildings.
3. Propose a certificate for the building assessment and for the neighborhood assessment.

In the under developing era of smart grids and energy communities connecting buildings, neighborhood-scale energy categorization will play a bigger role. By considering the energy infrastructure and interconnections at the district level as well as the specific building units, SmartLivingEPC seeked also to establish a new energy categorization system at the neighborhood level. As a consequence, a complex-level certificate was generated, encouraging neighborhood-level energy conservation. Six carefully chosen buildings in the Leitza area of Spain will serve as demonstration sites for the certification method.

2 Asset rating calculation methodology – BUILDING EPC

2.1 Indicators derived from SmartLivingEPC asset assessment

In order to develop more sustainable and energy-efficient building that are in line with the EU requirements it is important to analyze the building from multiple angles. The proposed procedure takes into account multiple kpi-s from building smartness to earthquake seismic risk.

The basic principles of the SmartLivingEPC project's indicator system revolve around thorough and integrated evaluations that take into account environmental sustainability, energy efficiency, and smart readiness. The approach places a strong emphasis on the necessity of precise data gathering and analysis, enhancing accuracy with the use of Building Information Modeling (BIM) and other digital tools. It also places a high priority on flexibility and adaptability, which enables the evaluation method to take into account different building types as well as upcoming developments in building technology. The project seeks to develop a rigorous and globally applicable system for assessing and improving building performance, eventually supporting more sustainable and efficient built environments. It does this by combining several performance measurements and adhering to established European standards.

Smart readiness indicators

The ***Total Smart Readiness Score*** is a composite metric that aggregates the overall smart capabilities of a building. It reflects the extent to which the building integrates smart technologies across various domains. The ***Total Smart Readiness Rating*** converts this score into a standardized rating, presented as a letter grade to simplify comparison across different buildings.

Smart Readiness Score, per Key Functionality - This indicator breaks down the smart readiness score by specific functionalities, such as heating, cooling, and lighting. It assesses how well each system within the building is equipped with smart technologies. This granular analysis helps identify strengths and weaknesses in the building's smart infrastructure, guiding targeted improvements.

Energy Performance and Operation - This indicator evaluates the building's efficiency in energy consumption and management. It considers how smart technologies optimize energy use, reduce waste, and enhance overall operational performance. This is crucial for lowering energy costs and minimizing environmental impact.

Response to User Needs - This measures how effectively the building's smart systems respond to occupant preferences and requirements. It includes aspects like automated lighting and climate control adjustments based on user behavior, contributing to improved comfort and satisfaction.

Energy Flexibility- Energy flexibility assesses the building's capability to adjust its energy demand in response to external signals, such as peak load times or price fluctuations. Smart readiness in this area enables better integration with smart grids and enhances the building's role in a dynamic energy system.

Smart Readiness Score - This score evaluates smart readiness based on various impact criteria, such as energy efficiency, maintenance, comfort, convenience, health, well-being, and accessibility.

Energy Efficiency - Energy efficiency focuses on the building's ability to minimize energy consumption while maintaining or improving performance. Smart technologies play a significant role in optimizing heating, cooling, lighting, and other energy-consuming systems.

Maintenance and fault prediction - This criterion evaluates the building's capacity to use smart technologies for predictive maintenance and fault detection. By identifying issues before they become serious, the building can reduce downtime and maintenance costs.

Comfort - Comfort assesses how well the building's smart systems maintain optimal indoor conditions, such as temperature, humidity, and lighting, enhancing the living or working environment for occupants.

Convenience - Convenience measures the ease of use and automation provided by smart technologies. This includes features like automated control systems, remote access, and user-friendly interfaces that simplify building management.

Health, well-Being, and accessibility - This criterion evaluates the impact of smart technologies on the health and well-being of occupants, as well as the building's accessibility. It includes air quality monitoring, ergonomic design, and systems that support individuals with disabilities.

Information to occupants - This indicator assesses how effectively the building provides occupants with relevant information, such as energy usage, indoor environmental conditions, and system status. Transparency and access to information empower users to make informed decisions about their environment.

Energy flexibility and storage*:* This evaluates the building's ability to store energy and adjust its consumption in response to supply and demand dynamics.

Smart Readiness Score, per Technical Domain

This indicator breaks down the smart readiness score by specific technical domains, assessing the integration and functionality of smart systems in each area:

- Heating: Evaluates smart capabilities in the building's heating systems, such as programmable thermostats and adaptive control systems.
- Domestic Hot Water: Assesses the smart integration in hot water systems, including efficient water heating and usage monitoring.
- Cooling: Measures the effectiveness of smart cooling technologies, such as automated climate control and energy-efficient air conditioning.
- Ventilation: Examines the smart features in ventilation systems, including air quality sensors and automated airflow adjustments.
- Lighting: Evaluates smart lighting systems, including automated lighting control, occupancy sensors, and energy-efficient lighting solutions.
- Dynamic Building Envelope: Assesses the smart features of the building envelope, such as automated shading and insulation adjustments.
- Electricity: Measures smart integration in the building's electrical systems, including energy monitoring and smart grid connectivity.
- Electric Vehicle Charging: Evaluates the availability and smart features of electric vehicle charging infrastructure.
- Monitoring and Control: Assesses the overall effectiveness of smart monitoring and control systems, including building management systems and IoT integration.

In Table 1 are summarized the SRI indicators and their corresponding units:

Table 1: SRI assessment output data

Description	Symbol	Unit
Total smart readiness score	SR	%
Total smart readiness rating	SR_{class}	-
Smart readiness score, per key functionality Energy performance and operation Response to user needs Energy flexibility	SR_f	%
Smart readiness score, per impact criterion Energy efficiency Maintenance and fault prediction Comfort Convenience Health, well-being, and accessibility Information to occupants Energy flexibility and storage	SR_{ic}	%
Smart readiness score, per technical domain	SR_d	%

Heating Domestic hot water Cooling Ventilation Lighting Dynamic building envelope Electricity Electric vehicle charging Monitoring and control		

Environmental indicators

A wide range of indicators are used in the SmartLivingEPC project to assess various aspects of building performance and its environmental effect. The potential for climate change, ozone depletion, acidification, eutrophication (freshwater and marine), and photochemical ozone production are only a few of the many criteria covered by these indicators. The research also evaluates the possibility for global warming during the life cycle, water usage, operational energy performance, and the depletion of abiotic resources (minerals, metals, and fossil fuels). Additional metrics include the number, kind, and longevity of building materials; waste generation and transportation during building and destruction; and design concepts for flexibility, refurbishment, removal, recycling, and reuse. The project guarantees a comprehensive approach to sustainability and performance monitoring by assessing water usage during the building's use phase.

In Table 2 are summarized the environmental indicators and their corresponding units:

Table 2: Environmental assessment output data

Indicator Name	Indicator Description	Units
Climate change (global warming potential)	Indicator denoting the potential global warming resulting from the discharge of greenhouse gases into the atmosphere. Climate change is the consequence of human-induced emissions on atmospheric radiative forcing, specifically heat radiation absorption, which has been identified as a subject of paramount concern. Subsequently, this phenomenon may yield adverse ramifications on vital components such as ecosystem health, human well-being, and material welfare. The majority of these emissions have been observed to accentuate radiative forcing, leading to an elevation in surface temperatures on Earth, commonly acknowledged as the greenhouse effect. Consequently, this indicator emphasizes the imperative areas of safeguarding, namely human health, the natural environment, and the built environment.	kg CO_2 equivalents per kg [kg CO_2 eq / kg]
Ozone depletion potential	Indicator of emissions to air that causes the destruction of the stratospheric ozone layer.	kg CFC 11 equivalents [kg CFC 11 eq]
Acidification potential	In the realm of environmental phenomena, a reduction in the pH level of rainwater and fog measurements ensues, subsequently eliciting adverse consequences for ecosystems. Such effects manifest in the leaching of soil nutrients and heightened metal solubility into the soil matrix. The ramifications of acidifying pollutants extend across diverse domains, including soil quality, groundwater, surface waters, living organisms, ecosystems, and even the integrity of constructed materials such as buildings. Among the chief	mole H+ equivalents [mol H+ eq.] kg SO_2 equivalents per kg [kg CO_2 eq / kg]

	contributors to acidification are emissions of sulfur dioxide (SO_2), nitrogen oxides (NOx), and ammonia compounds (NHx). Areas warranting particular concern and protection encompass both the natural environment and the constructed urban landscape, as well as human health and the safeguarding of vital natural resources.	
Eutrophication aquatic freshwater	In the realm of freshwater ecosystems, an observable phenomenon emerges in the form of amplified growth measurements of aquatic plants or the proliferation of algal blooms, both of which can be attributed to the elevated presence of nutrients. This influx of nutrients contributes to a state of excessive enrichment, resulting in the exacerbation of aquatic plant growth or the burgeoning of algal populations. Such a scenario warrants scholarly attention, as it pertains to the subject of freshwater ecotoxicity, which delves into the repercussions of toxic substances on the delicate balance and functionality of these vital aquatic environments.	kg P equivalents [kg P eq.]
Eutrophication aquatic marine	Marine ecosystem reaction measurement to excessive availability of a limiting nutrient.	kg N equivalents [kg N eq.]
Eutrophication terrestrial	Enhanced quantification of nutrient accessibility within the soil consequent to the infusion of botanical fertilizers.	mole N equivalents [mol N eq.]
Photochemical ozone formation	Indicator delving into the measurement and subsequent effects of nitrogen oxides (NOx) and non-methane volatile organic compounds (NMVOC) on the domains of 'Human Health' and 'Terrestrial Ecosystems' protection. Emphasizing photo-oxidant formation, which engenders the generation of reactive chemical species such as ozone through solar irradiation on specific primary air pollutants, the research explores the potential deleterious consequences of these reactive compounds on human health and the environment, including detrimental effects on crops. The pertinent areas of protection under scrutiny encompass human health, the built environment, the natural habitat, and essential natural resources.	kg NMVOC equivalents [kg NMVOC eq.]
Depletion of abiotic resources - minerals and metals	Indicator delving into the concept of "abiotic resource depletion," an essential metric for measuring the exhaustion of natural non-fossil resources. Abiotic resources encompass diverse natural sources, such as iron ore, crude oil, and wind energy, which are characterized by their non-living origin. This indicator holds significant prominence within sustainability discussions, and consequently, various methodologies have emerged to characterize contributions to this domain. The divergent approaches adopted in these methodologies often stem from disparities in problem definitions. As a result, the scope of this indicator may encompass solely natural resources or extend to encompass human health and the natural environment, thereby warranting comprehensive consideration.	kg Sb equivalents [kg Sb eq.]
Depletion of abiotic resources – fossil fuel	Indicator of the depletion of natural fossil fuel resources.	Mega Joules [MJ]

Water use	Indicator of the amount of water required to dilute toxic elements emitted into water or soil.	Cubic meters [m^3]
Use stage energy performance	"Operational energy consumption": primary energy demand measurement of a building in the use stage, generation of low carbon or renewable energy.	kilowatt-hours per square meter per year (kWh/m^2 /yr)
Life cycle Global Warming Potential	"Carbon footprint assessment" or "whole life carbon measurement": building's contribution to greenhouse gas (GHG) emissions measurement associated with earth's global warming or climate change.	kg CO_2 equivalents per square meter per year (kg CO_2 eq./m^2/yr
Bill of quantities, materials, and lifespans	The quantities and mass of construction products and materials, as well as estimation of the lifespans measurement necessary to complete defined parts of the building.	Unit quantities, mass, and years
Construction & demolition waste and materials	In the context of construction, renovation, and demolition activities, the aggregate volume of waste and materials produced serves as the basis for computing the diversion rate pertaining to reuse and recycling, adhering to the principles outlined in the waste hierarchy.	kg of waste and materials per m^2 total useful floor area
Design for adaptability and renovation	Building design extent assessment of facilitation future adaptation to changing occupier needs and property market conditions; a building proxy capacity to continue to fulfill its function and for the possibility to extend its useful service life into the future.	Adaptability score
Design for deconstruction, reuse, and recycling	In the realm of architectural design, the evaluation of the potential for future material recovery and reuse, encompassing disassembly considerations to optimize the ease of deconstructing essential building components, is imperative. This entails a comprehensive assessment of the feasibility of reutilizing and recycling said components, along with their associated sub-assemblies and constituent materials.	Deconstruction score
Use stage water consumption	The comprehensive quantification of water utilization for an average building inhabitant, encompassing the ability to distinguish between potable and non-potable water supplies, as well as facilitating the identification of regions facing water scarcity.	m^3/yr of water per occupant

Energy indicators

Heating, domestic hot water (DHW), cooling, ventilation, lighting, and building automation and, eventually, control (BAC) systems are only a few of the building systems for which the SmartLivingEPC project measures the primary energy consumption, both renewable and non-renewable. Every system has its energy consumption assessed for both thermal and electric vectors. By guaranteeing a comprehensive evaluation of energy sources and their efficiency of use, these indicators encourage the move, whenever feasible, towards renewable energy. Together with calculating non-renewable and renewable primary energy consumption for both thermal and electric vectors, the SLE calculation methodology offers a thorough picture of the energy profile of a building.

Together with energy consumption figures, the SmartLivingEPC project assesses the building's energy performance class overall and for each system—heating, DHW, cooling, ventilation, and lighting. This categorization promotes an all-encompassing strategy to energy efficiency and helps pinpoint areas that would need renovation and modernization work. Indicators that demonstrate the building's capacity to return excess energy to the grid include the Renewable Energy Ratio (RER), which calculates the percentage of energy derived from renewable sources, and the amount of exported primary energy, for both electric and thermal vectors. These guiding ideas stress the need of switching to sustainable energy sources and enhancing the energy efficiency of every building system.

The energy indicators are summarized in the following table:

Table 3: Energy indicators

No	ENERGY PERFORMANCE INDICATORS at Building Level	MU	ASSET calculation methodology according to:
1	Non-Renewable Primary Energy Consumption, Thermal vector	kWh/m2,y	EN ISO 52000-1
2	Non-Renewable Primary Energy Consumption, Electric vector	kWh/m2,y	EN ISO 52000-1
3	Renewable Primary Energy Consumption, Thermal vector	kWh/m2,y	EN ISO 52000-1
4	Renewable Primary Energy Consumption, Electric vector	kWh/m2,y	EN ISO 52000-1
5	Total primary energy consumption	kWh/m2,y	EN 52000-1
6	Building's Energy Overall Performance Class	A…G	SLE class, EN ISO 52003-1
7	Renewable Energy Ration (RER)	%	EN ISO 52000-1
8-9	Exported Primary Energy, Electric vector & Thermal vector	kWh/m2,y	EN ISO 52000-1

The calculation methodology for all 9 indicators from Table 3 was detailed in D2.4. The total primary energy includes both renewable and non-renewable primary energy, as stated in the new EPBD.

According to EPBD definitions, total primary energy should be calculated from delivered energy, which refers to the energy supplied through the assessment boundary. In order to clarify the definition of the assessment boundary, and to uniformize the primary energy calculation, it is proposed to calculate EP-values based on total primary energy from delivered energy to the building site (the same for the CO_2 emissions). This approach ensures that the on-site generated and self-used renewable electricity and ambient energy, which are not treated as delivered energy, do not increase the EP-value. SLE calculation is based on the same energy flows for non-renewable, total primary energy, but with different factors. This method aligns with the EPBD objective of very low energy consumption and high share of energy from renewable sources.

The assessment boundary, which is proposed for the SLE calculation procedure, is shown in figure 1, respecting the EN ISO 52000-1 building assessment boundary. This case is complemented with a building site boundary for primary energy calculation. Ambient energy and on-site generated renewable energy are not added to the total primary energy indicator, as the goal is to minimize total primary energy from the energy grids.

With building site boundary on **Figure 1**, total primary energy indicator is calculated from delivered energy to building site, i.e. from delivered energy with nearby and distant origin.

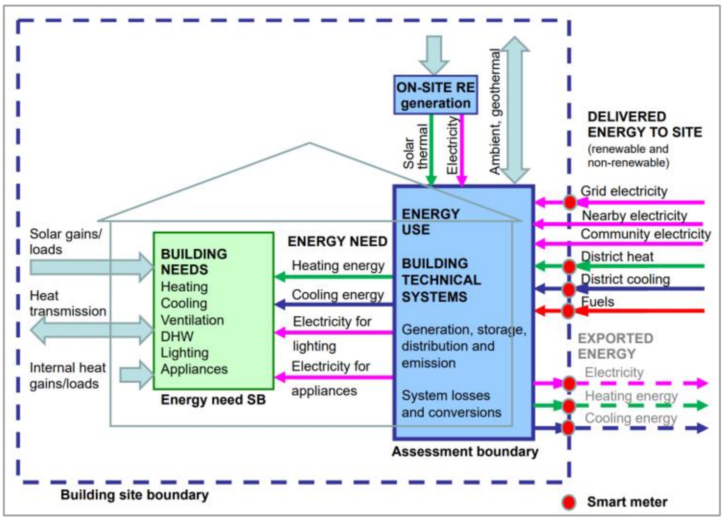


Figure 1: Building site boundary for primary energy calculation that complements building assessment boundary of EN ISO 52000-1 [1]

Non-energy indicators

A thorough collection of non-energy indicators are part of the SmartLivingEPC project, which assess several parts of building comfort and safety.

One subset of proposed indicators measure artificial lighting source temperature, colour rendering index (CRI), and artificial illuminance level for **visual comfort**. With suitable brightness, colour accuracy, and colour temperature to improve visual experiences and productivity, these measurements guarantee that lighting conditions are friendly to occupant comfort.

Acoustic comfort is assessed by means of parameters including reverberation time (RT60), global sound pressure level, and sound pressure level/frequency. By measuring the building's acoustics, one can guarantee a comfortable acoustic environment, lower noise pollution, and improve occupant well-being. The project assess the Predicted Mean Vote (PMV) index, Predicted Percentage of Dissatisfied (PPD), and operating temperature for thermal comfort. By evaluating how effectively the interior temperature and general thermal environment satisfy occupant comfort needs, these indicators guarantee a balance between heating, cooling, and human comfort.
Because **radon risk rating** and **CO_2 levels** are essential for preserving a healthy interior environment, they are used to assess **indoor air quality**. These markers support in the detection and reduction of pollutants that may be harmful to the health of the inhabitants.

A building's **accessibility index** grade also gauges how easily and inclusively a building is for people with impairments.

To encourage sustainable water, use within buildings, **water consumption efficiency** is evaluated, pointing up places where water usage may be improved.

In order to guarantee that safety precautions are in place to protect residents in earthquake-prone areas, the **earthquake hazard risk** indicator assesses the building's resistance to seismic activity. These all-encompassing measures back up the objective of the SmartLivingEPC project to develop liveable, secure, and environmentally friendly constructed environments.

The non-energy indicators are summarized in the following table:

[1] REHVA Technical Guidance for EPBD Implementation, https://www.rehva.eu/fileadmin/user_upload/2024/EPBD_Guidance_2024.pdf

Table 4: Non-energy indicators

No	NON-ENERGY INDICATORS at Building Level	MU	ASSET calculation methodology according to
1	Visual comfort – artificial illuminance level	Lux	EN 16798-1:2019/ ISO/CIE 20086:2019(E) + SLE
2	Visual comfort Color rendering (CRI)	-	EN 16798-1:2019/ ISO/CIE 20086:2019(E) + SLE
3	Visual comfort Artificial lighting sources temperature	K	EN 16798-1:2019/ ISO/CIE 20086:2019(E)) + SLE
4	Acoustic comfort – Sound pressure level/frequency	dB	EN 16798-1:2019/ SR EN ISO 717-1 + SLE
5	Acoustic comfort – Global sound pressure level	dB(A)	EN 16798-1:2019/ SR EN ISO 717-1 + SLE
6	Acoustic comfort – Reverberation time RT60	sec	EN 16798-1:2019/ SR EN ISO 11654 + SLE
7	Thermal comfort – Operative temperature	ºC	EN 16798-1:2019/ISO 7730:2005+ SLE
8	Thermal comfort – PMV index	-	EN 16798-1:2019//ISO 7730:2005+ SLE
9	Thermal comfort – PPD	%	EN 16798-1:2019//ISO 7730:2005 + SLE
10	Indoor air quality – CO_2 level	PPM	EN 16798-1:2019 + SLE
11	Indoor air quality - Radon risk rating	-	SLE rating
12	Accessibility index rating	-	SLE rating
13	Water consumption efficiency rating	%	SLE rating
14	Earthquake hazard risk	-	EU standard on earthquake risk assessment from SR1 to SR4 (SR – seismic risk)

2.2 Rating procedure

2.2.1 Rating of SRI

A composite measure called the Total Smart Readiness Score assesses how well smart technologies are integrated into a building overall across many areas. To what degree smart technology are used to improve the performance, efficiency, and user experience of the building is indicated by this score. The Total Smart Readiness Rating then simplifies comparisons between buildings and facilitates stakeholder understanding and benchmarking of smart readiness by converting this extensive score into a standard letter grade. An indicator that unravels the whole smart readiness score into certain functionalities—heating, cooling, lighting, and more—is the Smart Readiness Score, per Key Function. This detailed examination helps identify the advantages and disadvantages of the smart infrastructure of the building by evaluating the degree to which each system is outfitted with smart technology. Through the insightful information this thorough assessment offers, particular areas can be optimized and improved upon.

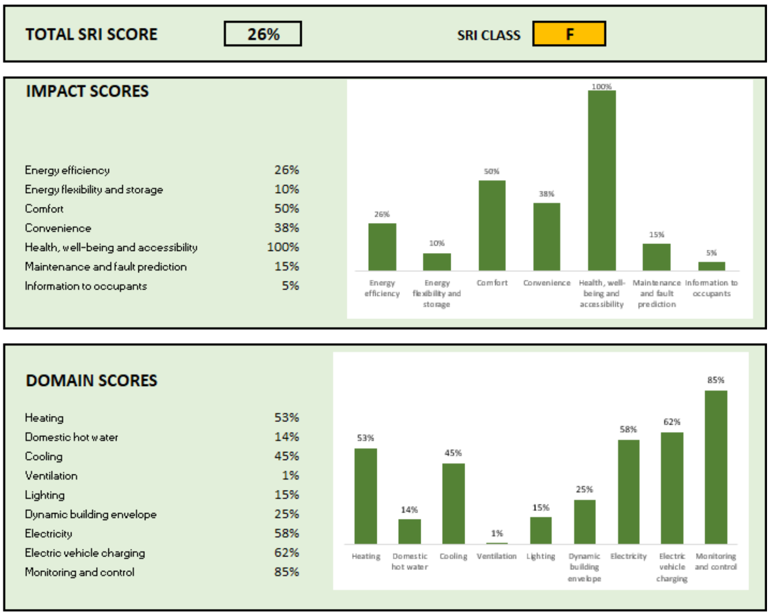


Figure 2: Example of rating of SRI

2.2.2 Rating of energy indicators

The SmartLivingEPC (SLEPC) assessment system provides a scoring technique to translate the computed primary energy consumption into a readily accessible and comparative energy performance classification. The energy score is quantified as a percentage and afterward allocated to a performance class ranging from A to G, in line with the following mapping. We propose a rating score based on the same grading scale methodology adopted at EU level for SRI. Thus, we have changed the primary energy class to a score similar to that of SRI. The approach simplifies the difficult calculations and diverse parameters connected with measuring the energy efficiency of a building into a comprehensible score and categorization. The application of scores and classifications provides valuable information that can help educated decision-making processes connected to energy efficiency increases, financial investments, and the formulation of regulations. Moreover, the score is needed later on for the assessment between energy, non-energy, environmental and SRI values.

The methodology to set the energy performance building class [A to G] follows the indications in EN ISO 52003-1, i.e. stepped scale option with geometric series to express the upper limits of the energy classes,

$$Y = \sqrt{2}^{(n-n_{ref})}$$ [equation 1]

where:

Y is the index computed for the case of 7 classes (see Table 5)

n is the position of energy class on the scale and

n_{ref} is the position of the energy class for reference point on the scale.

It has been proposed to place the reference point on the limit of classes 4 and 5 (n_{ref} = 4)

Table 5: Primary energy class to score

Primary energy class	Multiplication index [according to EN ISO 52003-1]	Score
	0,00	100
A		…
	0,35	82,5
B		…

	0,50	75,0
C		…
	0,71	64,5
D		…
	1,00 **(reference building)**	50,0
E		…
	1,411	29,45
F		…
	2,00	0
G		

The equation to compute the energy score for a building is

$$y = -1{,}5833x^2 - 2{,}7298x + 99{,}936 \quad \text{[Equation 2]}$$

where

y is the building energy score (between 100 and 0) and

x is the relative primary energy index (between 0 and 2) , the same Y in the [equation 1]

Two important indicators—**delivered energy and primary energy**—are used by the SmartLivingEPC project to assess the asset building energy use. **Delivered energy** is the energy that different end-use systems in a building—lighting, heating, ventilation, DHW, and cooling—directly consume. This is the energy needed for the building to operate properly. By contrast, **primary energy** encompasses the whole energy cycle, beginning with the extraction of primary energy resources and ending with their transformation into forms that may be used inside the building. Including energy losses during production, transmission, and distribution, this wider perspective offers a thorough picture of the environmental effects of energy use on a facility.

The SmartLivingEPC project assesses building performance using a wide range of energy sub-indicators listed in D2.4 (energy needs for heating, cooling etc., delivered energy for heating, cooling etc. SLE energy indicators allow for the differentiation of electric and thermal vectors, as well as renewable and non-renewable sources. Primary energy consumption in both non-renewable and renewable forms was evaluated.

All taken together, these indicators provide a comprehensive picture of the energy performance of a building. Together with offering thorough assessments of specific systems, they also add to a thorough performance categorization that takes into account several aspects of sustainability and energy efficiency. Stakeholders can make well-informed decisions when the SmartLivingEPC rating system efficiently evaluates building performance in accordance with European standards, EN ISO 52000 series.

A critical feature in estimating primary energy under the SmartLivingEPC framework is the use of national conversion factors. Converting delivered energy into primary energy units requires these elements, which represent the specific energy mix, conversion efficiency, and effectiveness of each nation's distribution networks. These conversion parameters particular to each country will to be user-handled by the SmartLivingEPC rating system to guarantee correct and meaningful primary energy estimates. Through its compliance with national grading systems and protocols, SmartLivingEPC offers an advanced and flexible assessment of building performance throughout several EU member states. A specific tool for computing energy ratings has been developed, demonstrated by the primary energy rating figure, although it is highlighted that not all EU nations have energy ratings for all sorts of consumers such as heating, cooling, DHW, lighting, and ventilation.

2.2.3 Rating of non-energy indicators

Non-energy variables are just as important in building evaluations as energy performance, as the SmartLivingEPC (SLEPC) rating system emphasizes. Through an emphasis on important elements that guarantee occupant well-being, health, and environmental sustainability, these indicators offer a thorough picture of a building's overall performance. By including non-energy characteristics, the SLEPC rating accomplishes a comprehensive assessment that acknowledges the importance of elements other than energy use.

The asset calculation procedures of all non-energy indicators on one hand and the classification and grading methodologies of these on the other hand, are presented in detail in the deliverable D2.4.

In order to guarantee occupant health and productivity, Indoor Environmental Quality (IEQ) assesses air quality, thermal comfort, and acoustic performance. Efficiency in using water resources measures how well appliances, fixtures, and water recycling systems work. While the structural integrity assessment looks at buildings in seismic regions for earthquake resilience, the radon risk assessment assesses possible exposure to radon gas.

The assessment of thermal comfort is an essential component of the SmartLivingEPC (SLEPC) assessment system, which prioritizes Indoor Environmental Quality (IEQ). Not only does energy efficiency benefit greatly from optimal thermal conditions, but so do the productivity and well-being of building inhabitants. The SLEPC technique includes several key metrics for evaluating thermal comfort: the Predicted Mean Vote (PMV) and the Percentage Of Persons Dissatisfied (PPD).

The assessment approach for PMV analyses elements such as air temperature, mean radiant temperature, air velocity, humidity, clothing insulation, and metabolic rate. The PMV scale extends from -3 to +3, with values approaching zero indicating optimal comfort. Separate estimates for winter and summer handle seasonal fluctuations.

Table 6: Example of thermal comfort rating for two thermal zones

		Zone 1	Zone 2
PMV_winter		-0.85	-0.82
PPD_winter		20.33%	19.13%
	Score	80.8	82.0
	Rating	B	B
	Overall score	81.8	
	Overall rating	B	

Understanding that various parts of a building have unique needs and qualities, the SLEPC approach uses a zonal type of analysis to offer a thorough assessment. Every zone is evaluated separately taking into account elements like acoustics, thermal comfort, air quality, and artificial and natural lighting. This method recognizes that functional needs and environmental circumstances might vary throughout zones, as in the case of a school and a library, or of kitchens and restrooms contrasted to living spaces.

Variations in energy use patterns are another factor taken into account by the zonal approach, which can have a big impact on the building's total energy efficiency. Through the division of the building into smaller sections and their independent assessment, the SLEPC system guarantees a comprehensive assessment of every zone. After combining these separate ratings, a weighting procedure that takes into account the surface area of each zone in relation to the overall building area yields the building's overall SLEPC rating.

An essential part of evaluating Indoor Environmental Quality (IEQ) is Indoor Air Quality (IAQ), as emphasized by the SmartLivingEPC (SLEPC) rating system. Two main indicators are the main emphasis of the system to give a thorough assessment of IAQ: radon risk and carbon dioxide (CO2) concentrations. Poor ventilation, as indicated by high CO2 levels, can have a negative impact on both occupant comfort and cognitive function. A building's ventilation system's efficiency is evaluated and tenant health is guaranteed by monitoring CO2 levels. Furthermore, buildings can store up naturally occurring radioactive gas radon, particularly in basements, which presents serious health concerns including higher rates of lung cancer. Protection of building occupants' health and safety depends on radon risk assessment.

Parts per million (ppm) CO2 levels can be calculated in several building locations and assessed against predetermined standards to ascertain ventilation efficiency and general air quality. Low, Medium, High, and Extreme are the four degrees of risk for radon, which are measured by specialist detectors. The rating of risk is done using the EU Radon map according to the GPS position of the building. Through addressing both ventilation and possible radon exposure, this systematic approach guarantees a comprehensive and accurate assessment of IAQ within the SLEPC system, promoting healthier and safer indoor environments.

Table 7: Example of air quality rating for two thermal zones

Analysed zones			
		Zone 1	Zone 2
AVERAGE CO2 (ppm)		1500	486
ZONE COMPLIANCE		66.67%	100.00%
		E	A
ALL ZONES COMPLIANCE		83.3%	
		C	

Light incident on a surface is measured in lux, or illumination. For comfort, to maximise task performance, and to minimise eye strain, appropriate lighting settings are essential. Expressed as a percentage of outdoor illumination, the Daylight Factor assesses how much natural light is present in a given space. Because it improves mood and productivity, natural light is an essential component of building performance assessment. When colour accuracy is crucial, as it is in settings like art studios, retail, and medical facilities, colour rendering describes how well artificial light sources depict the colours of objects. Given in Kelvin (K), the colour temperature describes how warm or cold artificial lighting is, affecting mood and concentration and hence changing in significance depending on the building area. Weighted according to the surface area of each zone, these visual comfort indicators guarantee proportionate representation in the final SLEPC assessment.

Table 8: Example of visual comfort rating for two thermal zones

INPUT DATA	Analysed zones	
	1	2
Score	73.1	86.1
Rating	C	B
Overall score	82.4	
Overall rating	B	

Using two main metrics - global sound pressure level and reverberation time - the SmartLivingEPC (SLEPC) evaluation system emphasizes the value of acoustic comfort as a fundamental component of Indoor Environmental Quality (IEQ). The decibel (dB(A)) global sound pressure level assesses how loud an environment is; excessive levels may be uncomfortable, stressful, and less productive. Second-measured reverberation time tells how long it takes for sound decay in a closed space; prolonged reverberation can impair speech comprehension and deteriorate music quality. These measurements guarantee a thorough assessment of acoustic comfort, improving general occupant happiness and well-being in both living and working areas.

Table 9: Example of noise comfort rating for 2 thermal zones

INPUT DATA	Analysed zones	
	1	2
Frequency (Hz)	Rating sound pressure level & global sound pressure level	
125 Hz	A	B
250 Hz	A	B
500 Hz	A	A
1000 Hz	A	A
2000 Hz	A	C
4000 Hz	A	A
Lp (dB)	A	B
Global dB(A)	B	D
	Rating reverberation time	
Target reverberation (sec)	0.64	0.64

RT60(sec)	0.60	0.47
Rating	B	D
	Final rating	
Zone rating	B	C
Building rating	C	

Evaluating how accessible and adaptive a building is for people with disabilities requires the accessibility assessment included in the SmartLivingEPC (SLEPC) rating system. From 'Poor' to 'Excellent,' this evaluation is based on things like the size of doors and corridors, the presence of ramps and elevators, and the signage. High accessibility requirements improve building usability for all residents and encourage diversity.

Classifying buildings into four seismic risk levels (SR1 to SR4), the SLEPC methodology also assesses earthquake risk. Whereas SR2 implies a high risk of structural deterioration without stability loss, SR1 shows a considerable vulnerability to structural collapse. Buildings predicted to operate well under current regulations are indicated by SR4, whereas those vulnerable to non-structural damage are indicated by SR3. The possible hazards connected to seismic activity are identified and reduced in part by this classification.

Assessed by a number of criteria, including the efficiency of water fixtures (faucets, showerheads, toilets), appliances (dishwashers, washing machines), and water reuse and recycling systems (greywater recycling, rainwater harvesting), water efficiency is another essential element of the SLEPC rating. Furthermore taken into account are the effectiveness of landscape irrigation systems and the installation of leak monitoring and repair systems.

Through the incorporation of these factors and the assignment of suitable weights, the SLEPC grading system offers a thorough and useful assessment of the accessibility, earthquake risk, and water efficiency of a building.

ACCESIBILITY	
Information	Score
Fair: The building has some accessibility features, but improvements are needed to ensure compliance with accessibility standards and regulations	65.00

EARTHQUAKE SEISMIC CLASS	
Information	Score
Seismis class 3 - SR 3 This category includes buildings that may suffer minor damage in the event of an earthquake. For example, plaster may fall, cracks and fissures may appear in the walls, without endangering the lives of the occupants.	100.00

WATER EFFICIENCY	
Information	Score
Poor: Water consumption is significantly above the recommended level for the building type and occupancy rate, and no rainwater harvesting or graywater reuse systems are in place.	25.50

Figure 3: Example of rating for accessibility, earthquake seismic class and water efficiency

Each non-energy indication in the SLEPC rating system has an equal default weighting value. Users are free to change these weightings, though, in accordance with their requirements or priorities. Through the incorporation of these factors and the assignment of suitable weights, the SLEPC grading system offers a thorough and useful assessment of the accessibility, earthquake risk, and water efficiency of a building.

This all-inclusive method adds to the evaluation of the Indoor Environmental Quality (IEQ) overall and provides insightful information for focused enhancements to raise the standard of buildings.

2.2.4 Rating of environmental indicators

The integration of environmental sustainability is a fundamental principle within the SmartLivingEPC (SLEPC) rating system. The primary objective of the system is to offer a thorough assessment of the environmental impact of a building, encompassing a range of indicators that evaluate the building's ecological footprint and its overall performance. The indicators have been specifically developed to conform to the Level(s) framework, which is a European methodology utilized for evaluating and disclosing the sustainability aspects of buildings. The indicators were presented in Table 2.

Each of these indicators is computed using defined techniques to assure precision and comparability. Within the SLEPC rating scheme, the allocation of weights for each indicator is initially established as equal, with each indicator being assigned a weight of 5.88. Consequently, the cumulative weight of all indicators amounts to 100.

This technique maintains equilibrium by assigning equal significance to every facet of environmental impact and sustainability within the comprehensive evaluation. Nevertheless, it is important to acknowledge that the weighting of each indication can be altered, allowing for adjustments to the value of 5.88 if deemed appropriate by an energy auditor. In places characterized by a notable degree of water shortage, the 'Water Use' indicator may be accorded greater significance in the evaluation process. The inherent flexibility of the SLEPC rating system enables it to effectively accommodate and respond to unique environmental circumstances and individual priorities. A calculation procedure of the score for the environmental reference values will be conceived during the project. Based on these references, a final score and an environmental class can be determined.

LCA Indicators				
		Project value	Weighting	
			default	user
Climate change (global warming potential)	*kg CO2 equivalents per kg [kg CO2 eq / kg]*	150	5,88%	
Ozone depletion potential	*kg CFC 11 equivalents [kg CFC 11 eq]*	37,5	5,88%	
Acidification potential	*kg SO2 equivalents per kg [kg CO2 eq / kg]*	48,5	5,88%	
Eutrophication aquatic freshwater	*kg P equivalents [kg P eq.]*	6,5	5,88%	
Eutrophication aquatic marine	*kg N equivalents [kg N eq.]*	7,5	5,88%	
Eutrophication terrestrial	*mole N equivalents [mol N eq.]*	8,5	5,88%	
Photochemical ozone formation	*kg NMVOC equivalents [kg NMVOC eq.]*	9,5	5,88%	
Depletion of abiotic resources - minerals and metals	*kg Sb equivalents [kg Sb eq.]*	10,5	5,88%	
Depletion of abiotic resources – fossil fuel	*Mega Joules [MJ]*	11,5	5,88%	
Water use	*Cubic meters [m3]*	12,5	5,88%	
Use stage energy performance	*kilowatt-hours per square meter per year (kWh/m2 /yr)*	100	5,88%	
Life cycle Global Warming Potential	*kg CO2 equivalents per square meter per year (kg CO2 eq./m2/yr)*	14,5	5,88%	
Bill of quantities, materials, and lifespans	*Unit quantities, mass, and years*	15,5	5,88%	
Construction & demolition waste and materials	*kg of waste and materials per m2 total useful floor area*	16,5	5,88%	
Design for adaptability and renovation	*Adaptability score*	2	5,88%	
Design for deconstruction, reuse, and recycling	*Deconstruction score*	8	5,88%	
Use stage water consumption	*m3/yr of water per occupant*	19,5	5,88%	
			100,00%	0%

Figure 4: Example of LCA indicators with default weighting

2.2.5 Final rating

The SmartLivingEPC (SLEPC) rating system uses a thorough process to assess a building's performance in terms of both energy and non-energy aspects across a number of metrics. Finding and rating each indicator - Smart Readiness Indicators (SRI) for smart capabilities, energy efficiency metrics for heating, cooling, DHW, ventilation and lighting systems, and non-energy indicators like Indoor Air Quality (IAQ), i.e. thermal comfort, visual comfort, acoustic comfort, plus the accessibility level, the seismic risk, and water efficiency - is the first step. Using LEVEL(S) methods, which take into account life cycle analysis, water usage, and the possibility of global warming, environmental effects are evaluated. **Every part receives a score according to the particular requirements.**

The second stage is putting a weighting strategy into place to equalize the significance of different metrics. Although all non-energy indicators have identical default weighting values, users can change these weights according to their needs or preferences, guaranteeing a flexible and contextually appropriate evaluation framework.

Ultimately, the SLEPC grading system adds together the weighted scores to determine the building's total performance score. A final class rating ranging from A to G is then calculated from this score; a higher score denotes greater performance. With its thorough and useful assessment of a building's performance, this methodology eventually promotes sustainability and occupant wellbeing while addressing smart readiness, energy efficiency, and other non-energy aspects.

	Class (-)	Score (-)	Weighting *default*	Weighting *user*	Class (-)	Score (-)
ENERGY	E	54.72	25		D	60.23
LCA	B	85.00	25			
NON-ENERGY	C	75.55	25			
SRI	F	25.64	25			
				0	60.23 D	

Figure 5: Example of SMARTLIVING EPC rating

2.2.6 Study case

The main building of Frederick's University at Limassol Campus is a three-storey building covering an area of 4021 square meters. The building was constructed in 1996. The building style adheres to the typical architectural conventions observed in Cypriot buildings during that period. Specifically, it is characterized by a reinforced concrete framework, brick walls, and double-glazed windows. The Limassol campus building of Frederick University is a multifunctional structure that accommodates several facilities, including educational, administrative, and other functions. The facility accommodates a collective sum of ten laboratories, four studios, twelve classrooms, thirty-one office spaces, and a ground floor cafeteria-restaurant. The facility accommodates an estimated total of 715 individuals, comprising academic personnel, administrative personnel, and students, for the year 2021. Additionally, it encompasses the centralized management of heating, ventilation, and air conditioning (HVAC) equipment.

Figure 6: Pilot Building – Frederik University

Energy needs details :

- Heating: Electric (e.g. Gas, District Heating, Electric, etc.) -> 30 kWh/m²/year
- Cooling: 40 kWh/m²/year
- Ventilation: N/A kWh/m²/year
- Total Energy Needs: 110 kWh/m²/year

Smart readiness indicator

The building scores a 28% overall SRI. Energy flexibility 9,6%, response to user needs 36,5%, and energy performance and operation 36,7% are the scores per main functionality. The Figure that follows displays the impact and domain scores.

IMPACT SCORES	
Energy efficiency	49%
Energy flexibility and storage	10%
Comfort	47%
Convenience	21%
Health, well-being and accessibility	38%
Maintenance and fault prediction	25%
Information to occupants	40%
	33%

DOMAIN SCORE	
Heating	37%
Domestic hot water	0%
Cooling	37%
Ventilation	0%
Lighting	51%
Dynamic building envelope	0%
Electricity	42%
Electric vehicle charging	0%
Monitoring and control	17%

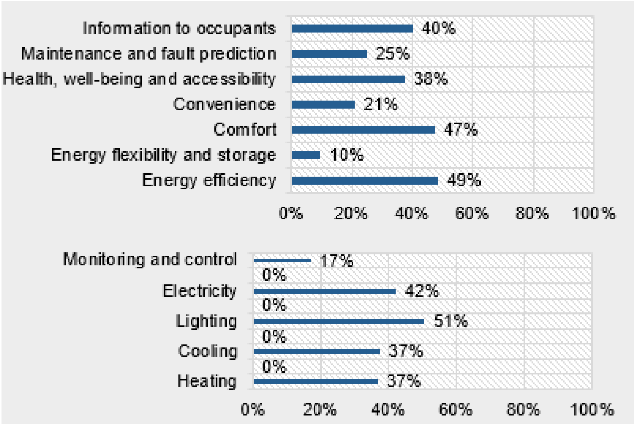
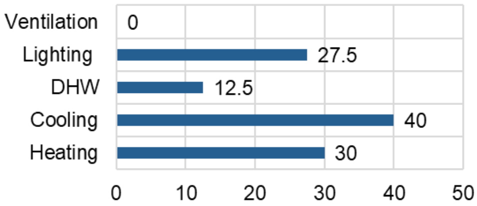


Figure 7: SRI index for Frederick's University

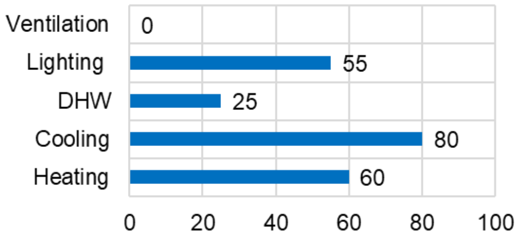
With this score, the building is rated F.
As concerns the energy consumption and based on the disposable data, the delivered energy is:

FINAL ENERGY (kWh/m²/year)			
	Thermal	Electric	Total
Heating	0	30	30
Cooling	0	40	40
DHW	0	12.5	12.5
Lighting	0	27.5	27.5
Ventilation	0	0	0
TOTAL	0	110	110



Considering a primary conversion factor of 2.5 for electricity, where 20% is renewable, then:

PRIMARY NON-RENEWABLE ENERGY (kWh/m²/year)			
	Thermal	Electric	Total
Heating	0	60	60
Cooling	0	80	80
DHW	0	25	25
Lighting	0	55	55
Ventilation	0	0	0
TOTAL	0	220	220



The 20% renewable from electricity, thus

RENEWABLE (kWh/m²/year)			
	Thermal	Electric	Total
Heating	0	15	15
Cooling	0	20	20
DHW	0	6.25	6.25
Lighting	0	13.75	13.75
Ventilation	0	0	0
TOTAL	0	55	55

Considering the reference building to be 150 kWh/m2/year, then:

PRIMARY TOTAL ENERGY (kWh/m²/year)			
	Thermal	Electric	Total
Heating	0	75	75
Cooling	0	100	100
DHW	0	31.25	31.25
Lighting	0	68.75	68.75
Ventilation	0	0	0
TOTAL	0	275	275
REFERENCE	0	-	**150**

This translates with a score of 54.55/100 and a class D. This is an example only and the analysis should be done using the method from 52003-1.

For the LCA indicators, proposed thresholds are used at this stage (values need later revision):

1. Climate Change (Global Warming Potential)
Low: < 10 kg CO2 eq/m²/year
Medium: 10-25 kg CO2 eq/m²/year
High: > 25 kg CO2 eq/m²/year

2. Ozone Depletion Potential
Low: < 0.0005 kg CFC-11 eq/m²/year
Medium: 0.0005-0.001 kg CFC-11 eq/m²/year
High: > 0.001 kg CFC-11 eq/m²/year

3. Acidification Potential
Low: < 0.1 mol H+ eq/m²/year
Medium: 0.1-0.5 mol H+ eq/m²/year
High: > 0.5 mol H+ eq/m²/year

4. Eutrophication Aquatic Freshwater
Low: < 0.005 kg P eq/m²/year
Medium: 0.005-0.01 kg P eq/m²/year
High: > 0.01 kg P eq/m²/year

5. Eutrophication Aquatic Marine
Low: < 0.05 kg N eq/m²/year
Medium: 0.05-0.1 kg N eq/m²/year
High: > 0.1 kg N eq/m²/year

6. Eutrophication Terrestrial
Low: < 0.1 mol N eq/m²/year
Medium: 0.1-0.5 mol N eq/m²/year
High: > 0.5 mol N eq/m²/year

7. Photochemical Ozone Formation
Low: < 0.05 kg NMVOC eq/m²/year
Medium: 0.05-0.1 kg NMVOC eq/m²/year
High: > 0.1 kg NMVOC eq/m²/year

8. Depletion of Abiotic Resources - Minerals and Metals
Low: < 0.01 kg Sb eq/m²/year
Medium: 0.01-0.05 kg Sb eq/m²/year
High: > 0.05 kg Sb eq/m²/year

9. Depletion of Abiotic Resources – Fossil Fuel
Low: < 50 MJ/m²/year
Medium: 50-150 MJ/m²/year
High: > 150 MJ/m²/year

10. Water Use
Low: < 50 m³/m²/year
Medium: 50-100 m³/m²/year
High: > 100 m³/m²/year

11. Use Stage Energy Performance
Low: < 50 kWh/m²/year

Medium: 50-100 kWh/m²/year
High: > 100 kWh/m²/year

12. Life Cycle Global Warming Potential

Low: < 10 kg CO2 eq/m²/year
Medium: 10-25 kg CO2 eq/m²/year
High: > 25 kg CO2 eq/m²/year

13. Construction & Demolition Waste and Materials

Low: < 10 kg/m²
Medium: 10-50 kg/m²
High: > 50 kg/m²

14. Design for Adaptability and Renovation

High Adaptability: > 80%
Medium Adaptability: 50-80%
Low Adaptability: < 50%

15. Design for Deconstruction, Reuse, and Recycling

High Reuse/Recycling Potential: > 80%
Medium Reuse/Recycling Potential: 50-80%
Low Reuse/Recycling Potential: < 50%

16. Use Stage Water Consumption

Low: < 50 m³/m²/year
Medium: 50-100 m³/m²/year
High: > 100 m³/m²/year

For this case study, the following data are proposed:

LCA Indicators						
		Project value	Weighting default	Weighting user	ference/thresho	Score
Climate change (global warming potential)	*kg CO2 equivalents per kg [kg CO2 eq / kg]*	5.5	5.88%		10	100%
Ozone depletion potential	*kg CFC 11 equivalents [kg CFC 11 eq]*	0.002	5.88%		0.0005	25%
Acidification potential	*kg SO2 equivalents per kg [kg CO2 eq / kg]*	0.05	5.88%		0.1	100%
Eutrophication aquatic freshwater	*kg P equivalents [kg P eq.]*	0.1	5.88%		0.005	5%
Eutrophication aquatic marine	*kg N equivalents [kg N eq.]*	0.09	5.88%		0.05	56%
Eutrophication terrestrial	*mole N equivalents [mol N eq.]*	0.25	5.88%		0.1	40%
Photochemical ozone formation	*kg NMVOC equivalents [kg NMVOC eq.]*	0.1	5.88%		0.05	50%
Depletion of abiotic resources - minerals and metals	*kg Sb equivalents [kg Sb eq.]*	0.2	5.88%		0.01	5%
Depletion of abiotic resources – fossil fuel	*Mega Joules [MJ]*	85.5	5.88%		50	58%
Water use	*Cubic meters [m3]*	78	5.88%		50	64%
Use stage energy performance	*kilowatt-hours per square meter per year (kWh/m2 /yr)*	130	5.88%		50	38%
Life cycle Global Warming Potential	*kg CO2 equivalents per square meter per year (kg CO2 eq./m2/yr)*	14.5	5.88%		10	69%
Bill of quantities, materials, and lifespans	*Unit quantities, mass, and years*		5.88%			
Construction & demolition waste and materials	*kg of waste and materials per m2 total useful floor area*	16.5	5.88%		10	61%
Design for adaptability and renovation	*Adaptability score*	53	5.88%		80	66%
Design for deconstruction, reuse, and recycling	*Deconstruction score*	25	5.88%		80	31%
Use stage water consumption	*m3/yr of water per occupant*	49	5.88%		50	98%
			100.00%	0%		54.17%

Figure 8: LCA indicators calculation and score

The final score will be the average thus 54.17 and the class D.

As concerns, the non-energy we have:

Calculated parameters		
Volume	105	300
CO2 exhalation (m3/h/pers)	0.02	0.013
CO2 exhalation (m3/h)	0.06	0.026
Infiltrations (vol/h)	0.5	1
Infiltrations (m3/h)	52.5	300
Total flow (m3/h)	202.5	300
Air changes inside (vol/h)	1.93	1
OUTPUT PARAMETERS		
AVERAGE CO2 (ppm)	1500	486
ZONE COMPLIANCE	66.67%	100.00%
	E	A
ALL ZONES COMPLIANCE	83.3%	
	B	

Figure 9: Indoor Air Quality score and class for the building two zones

INPUT DATA	Analyzed zones	
	1	2
Length (m)	10	10
Width (m)	2	5
Height (m)	2.5	2.5
Destination	Classrooms	Classrooms
Type window	Double glazing - PVC/Ai - low e	Single
Windows area (m2)	2	8
α (degree) - vertical	90	90
Maintenance factor	0.6	0.6
t coefficient	0.7	0.97
Luminaire temperature (K)	4000	4000
Luminaire color rendering	90	40
Type luminaire	LED lamp	LED lamp
Electric power (W)	40	200
Luminous flux (lm)	3600	18000
Illuminance (lx)	180	360
Zone surface (m2)	20	50
Percentage (%)	29%	71%
Target illuminance (lx)	300	300
Target color rendering	90	90
Target color temperature (K)	4000	4000
Target daylight	6%	6%
Daylight factor	2.0%	6.2%
Score	73.1	86.1
Rating	C	B
Overall score	82.4	
Overall rating	B	

Frequency (Hz)	Rating sound pressure level & global sound pressure level	
125 Hz	A	B
250 Hz	A	B
500 Hz	A	A
1000 Hz	A	A
2000 Hz	A	C
4000 Hz	A	A
Lp (dB)	A	B
Global dB(A)	B	D
	Rating reverberation time	
Target reverberation (sec)	0.64	0.64
RT60(sec)	0.60	0.47
Rating	B	D
	Final rating	
Zone rating	B	C
Building rating	C	

Figure 10: Visual and acoustic comfort non-energy indicators for two zones

Mean radiant temperature (oC)		
MRT	18.7	19.1
Calculation of indoor relative humidity (%)		
saturation vapor pressure	8.717	4.222
actual vapor pressure	566.63	274.42
absolute humidity (g/m3)	4.41	2.22
Moisture from occupants (g)	2400	800
Air change rate (vol/h)	0.1	0.6
Ventilation moisture (g/h)	27.811	399.181
absolute humidity (g/m3)	1.606	0.500
saturation vapor pressure	23.32596022	23.32596022
relative humidity	9.31%	2.90%
PMV_winter	-0.85	-0.82
PPD_winter	20.33%	19.13%
Score	80.8	82.0
Rating	B	B
Overall score	81.8	
Overall rating	B	

Figure 11: Thermal comfort non-energy indicator for two zones

For the accessibility the score is 85 , for earthquake seismic risk is 100 and water efficiency 75. The final rating for non-energy parameters is 85.56 and the class B.

The final rating with a similar weighting is :

	Class (-)	Score (-)	Weighting *default*	Weighting *user*	Class (-)	Score (-)
ENERGY	D	54.55	25		D	55.57
LCA	D	54.17	25			
NON-ENERGY	B	85.57	25			
SRI	F	28.00	25			
				0	55.57 D	

3 Asset rating calculation methodology – COMPLEX EPC

3.1 Indicators of the building complex SLEPC

The SmartLivingEPC neighborhood grading system incorporates environmental sustainability as one of its primary concepts. Its main goal is to present a thorough analysis of the environmental impact of a neighborhood using a variety of indicators that analyze societal, non-energy, environmental, and energy-related issues. The indicators have been carefully crafted to conform to the European Methods Framework, which is used in the assessment and revelation of metropolitan areas' sustainable attributes.

For the neighborhood a set of indicators that are proposed. These are summarized in the table below:

- Street Lighting- This indicator measures the availability of artificial lighting in public areas, impacting energy consumption, accessibility, personal security, road safety, and psychological comfort. It is calculated as the percentage of neighborhood surface illuminated over total pedestrian areas, using data from municipal GIS maps.
- Waste Generation - This indicator assesses the amount of waste generated per person compared to the national average. It is calculated by dividing the total waste generated by the number of inhabitants and normalizing this value by the average national waste generation, multiplied by 100. Data sources include municipal information and national public observatories.
- Waste Recycling Rate - This indicator measures the percentage of waste recycled within the neighborhood. It is calculated by dividing the total recycled waste by the total generated waste and multiplying by 100. Data is sourced from municipal information or public administration headquarters.
- Wastewater Processing Rate - This indicator denotes the availability of wastewater treatment services, measured as the percentage of neighborhood surface covered by the wastewater system over the total area, multiplied by 100. Data is obtained from municipal GIS maps.
- District Heating System - This indicator evaluates the energy used by centralized heating systems, calculated as the percentage of the building area heated by district systems over the total building area, multiplied by 100. Information is sourced from municipal GIS or the EPC.
- District Cooling System - Similar to the heating system, this indicator measures the energy used by centralized cooling systems, calculated as the percentage of building area cooled by district systems over the total building area, multiplied by 100. Data is sourced from municipal GIS or the EPC.
- District Heating Potential - This indicator assesses the potential for using waste energy from industry to provide heating, calculated as the percentage of thermal energy consumption that could be covered by residual heat over the total thermal energy consumption. Data is obtained from municipal GIS or the EPC.
- RES Ratio -This indicator measures the presence of renewable energy systems within the neighborhood, calculated as the percentage of buildings with RES installations. Data is collected through house-to-house surveys.
- PV Ratio - This indicator evaluates the presence of photovoltaic systems, calculated as the percentage of buildings with PV installations. Data is collected through house-to-house surveys.
- STC Ratio - This indicator measures the presence of solar thermal collectors, calculated as the percentage of buildings with STC installations. Data is collected through house-to-house surveys.
- GEO Ratio - This indicator evaluates the presence of geothermal systems, calculated as the percentage of buildings with GEO installations. Data is collected through house-to-house surveys.
- Potential RES Ratio - This indicator assesses the potential for buildings to connect to renewable energy systems at the district level, calculated as the percentage of buildings that could connect to RES. Data is obtained from municipal GIS or the EPC.
- PPA and VPPA Contracts - This indicator shows the number of buildings with active Power Purchase Agreements (PPA) and Virtual Power Purchase Agreements (VPPA), calculated as the percentage of buildings with these contracts. Data is obtained through surveys or records from energy companies.
- SMI Ratio - This indicator measures the installation of smart metering systems, calculated as the percentage of buildings with these systems. Data is obtained through surveys or energy company records.

- BEMS Ratio - This indicator evaluates the implementation of Building Energy Management Systems (BEMS), calculated as the percentage of buildings with BEMS. Data is obtained through surveys or energy company records.
- EV Charger Service Ratio - This indicator measures the capacity of EV chargers to meet the needs of the local fleet, calculated as the percentage of cars that can be fully charged daily by the installed capacity of EV chargers. Data is obtained from municipal GIS or the EPC.
- V2G EV Chargers Ratio - This indicator shows the percentage of EV chargers with Vehicle-to-Grid (V2G) capability within the total fleet of EV chargers. Data is obtained from municipal GIS or the EPC.
- EV Chargers by Building - This indicator measures the number of EV chargers per building, calculated as the percentage of buildings with EV chargers. Data is obtained from municipal GIS or the EPC.
- Transport Mode - This indicator reflects residents' transportation choices, using the "modal split" metric to show the frequency of different transport modes (car, public transport, bicycle, walking). Data is obtained from public administration or surveys.
- Fuel Cars Ratio - This indicator evaluates the presence of fossil fuel-powered vehicles, calculated as the percentage of such vehicles per inhabitant. Data is obtained through house-to-house surveys.
- EV Cars Ratio - This indicator measures the presence of electric vehicles, calculated as the percentage of EVs per inhabitant. Data is obtained through house-to-house surveys.
- Bike Lanes Ratio - This indicator measures the presence of bike lanes, calculated as the percentage of road length that is designated for bike lanes. Data is obtained from municipal GIS.
- Proximity -This indicator assesses the accessibility of essential services, calculated as the percentage of the population within walking distance (500m) to various services (schools, hospitals, public administration, banks, shops, sports centers, and leisure spaces). Data is obtained from OpenStreetMap and municipal GIS.
- Sharing Mobility - This indicator measures the adoption of car-sharing services, calculated as the percentage of inhabitants who have used a car-sharing application at least once. Data is obtained from car-sharing companies.
- Age of the Building Stock - This indicator shows the percentage of buildings over 30 years old in the neighborhood. Data is obtained from municipal GIS.
- Renovated 30-Year-Old Buildings This indicator measures the percentage of buildings over 30 years old that have been renovated. Data is obtained from municipal GIS.
- SmartLiving EPC Asset Rating This indicator shows the efficiency in energy consumption of buildings, derived from SmartLiving EPC assessments.
- SmartLiving EPC SRI - This indicator measures a building's ability to host smart-ready services, derived from SmartLiving EPC assessments.
- SmartLiving EPC LCA - This indicator evaluates the environmental impact of buildings based on their life cycle, derived from SmartLiving EPC assessments.
- SmartLiving EPC Non-Energy - This indicator measures the impact of non-energy aspects on buildings, derived from SmartLiving EPC assessments.
- Debt Ratio - This economic indicator shows the percentage of households that are late in paying utility bills. Data is obtained through house-to-house surveys or energy company records.
- Low Absolute Energy Expenditure - This indicator measures the percentage of households with energy expenditures less than half the national median. Data is obtained through house-to-house surveys or energy company records.
- High Share of Energy Expenditure in Income - This indicator measures the percentage of households with energy expenditures more than double the national median. Data is obtained through house-to-house surveys or energy company records.
- Thermal Comfort Threshold - This indicator measures the percentage of homes not meeting their thermal comfort needs. Data is obtained through house-to-house surveys.
- Heat Island This indicator - measures the local temperature increase in urban environments compared to peripheral areas. Data is obtained from sources like the EU Copernicus program.
- Air Quality - This indicator measures air quality in urban areas, expressing the percentage of the population affected by low air quality. Data is obtained from local or national regulations.
- Noise - This indicator measures the percentage of the population affected by high noise levels. Data is obtained from local or national regulations.

3.2 Rating assessment and benchmarking procedures of the SLEPC building complex

With the weighting mechanism used by the SmartLivingEPC (SLEPC) rating system, every Key Performance Indicator (KPI) can be given a **consistent weight of 2.70**, indicating **equal value**. Though it makes the procedure easier, this method ignores particular neighborhood needs. Alternatively, the weighting might be changed to match the individual requirements and culture of neighborhood residents or officials. This participatory action strategy incorporates stakeholders in the weighting process, ensuring the weights fit with the community's interests and aspirations. Because this approach enables neighborhoods to include their own identity and requirements into the final scores, local stakeholders find the certification more acceptable and meaningful.

Participatory weighing offers a number of benefits. It allows different communities to attach varying amounts of value to different topics, ensuring the final certificate respects neighborhood character and needs. When choosing neighborhoods, it also lets locals personalize weights according to interests. Furthermore, this approach keeps neighborhood comparisons from being made directly, which helps to avoid disputes and facilitates the political and administrative implementation of the SLEPC tool. The approach offers three possibilities for weighting: a Generic Rating with equal weights, a Neighborhood Rating employing participatory methodologies, and a European Rating reflecting broader preferences acquired through surveys. This flexibility makes sure the approach fits different requirements and situations, from more general municipal or individual assessments to local community evaluations.

DIMENSION	CATEGORY	INDICATOR	PROJECT VALUE	DEFAULT WEIGHTING	Class	RATING				
Environmental	Neighborhood services	Street Lighting and public area lighting	55	2.7	D	65	53	C	D	D
		Waste Generation	60	2.7	D					
		Waste Recycling rate	95	2.7	A					
		Wastewater Processing rate	85	2.7	B					
		District Heating System	18	2.7	G					
		District Cooling System	90	2.7	A					
		District Heating Potential	54	2.7	D					
	Renewable Energies	RES ratio	45	2.7	E	48		E		
		PV ratio	25	2.7	F					
		STC ratio	24	2.7	F					
		GEO ratio	85	2.7	B					
		Potential RES ratio	60	2.7	D					
	Demand Side Management	PPA and VPPA contracts	85	2.7	B	46		E		
		SMI ratio	48	2.7	E					
		BEMS ratio	5	2.7	G					
Infrastructure	EV chargers	EV charger service ratio	45	2.7	E	39	44	E	E	
		V2G EV chargers ratio	25	2.7	F					
		EV chargers by building	48	2.7	E					
	Mobility and transport	Modal Split	35	2.7	E	48		E		
		Fuel Cars ratio	18	2.7	G					
		EV Cars ratio	45	2.7	E					
		Bike lanes ratio	85	2.7	B					
		Proximity	85	2.7	B					
		Shared Mobility	18	2.7	G					
	Neighborhood Building Inventory	Age of the building stock	5	2.7	G	44		E		
		Renovated 30-year-old buildings	85	2.7	B					
		SmartLivingEPC Asset Rating	65	2.7	C					
		SmartLivingEPC SRI	49	2.7	E					
		SmartLivingEPC LCA	32	2.7	F					
		SmartLivingEPC Non Energy	28	2.7	F					
Social	Energy poverty	Debt ratio	18	2.7	G	71	69	C	C	
		Low absolute energy expenditure	85	2.7	B					
		High share of energy expenditure in income	85	2.7	B					
		Thermal comfort threshold	95	2.7	A					
	Quality of Life	Heat Island	100	2.7	A	68		C		
		Air Quality	80	2.7	B					
		Noise	24	2.7	F					
			53.8	100						

Figure 12: Example of complex asset rating

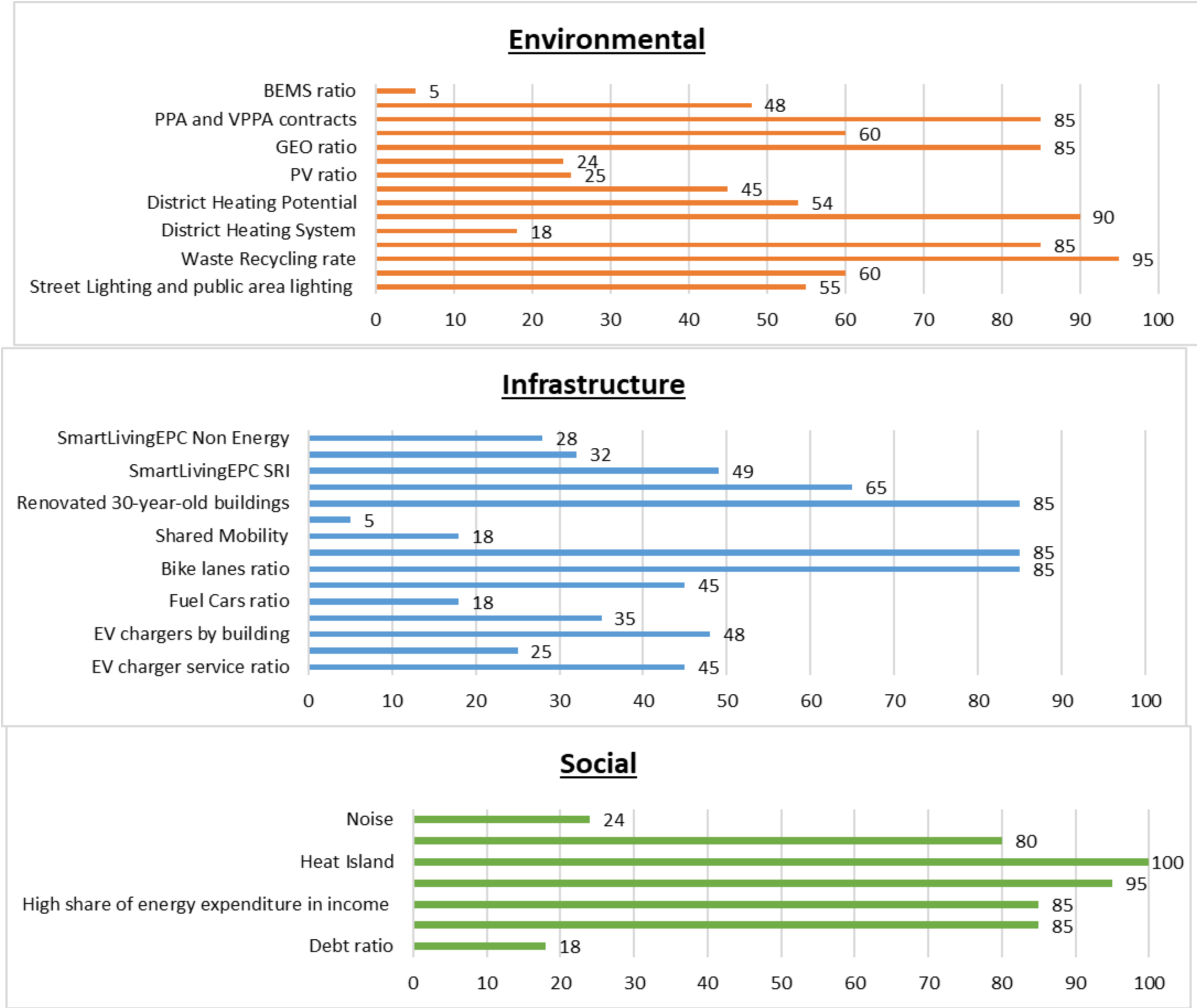


Figure 13: Example of data presentation

4 SmartLivingEPC outcomes

4.1 SmartLivingEPC building/neighborhood

An extensive summary of a building's performance, including its energy efficiency, environmental effect, and smart readiness, is intended to be provided by the SmartLivingEPC (SLEPC) Certificate. The interface of the certificate is crafted to be both intuitive and educational, offering a comprehensive overview of the building's characteristics and performance indicators. The building's address, geolocation (latitude and longitude), category (residential or commercial), physical parameters (total floor area, volume, and construction year), and local climate are among the first details listed in the certificate.

The performance summary gives a brief rundown of the building's advantages and disadvantages by offering an overall grade that is divided into categories including energy consumption, renewable ratio, indoor comfort, LCA indicators and smart readiness. It also describes the building's potential for development and offers suggestions on how to raise its performance class. Smart readiness, non-energy performance metrics (indoor air quality, thermal comfort, and water efficiency), environmental indicators (Life Cycle Global Warming Potential), and energy indicators (delivered energy, primary non-renewable and renewable energy, exported energy, all in kWh/m^2) are among the detailed metrics. Each subcategory is scored and categorized.

Administrative information is supplied for authentication, including the certificate number, issue date, validity duration, and the energy assessor's signature. Additionally, graphical representations of these metrics are included in the certificate.

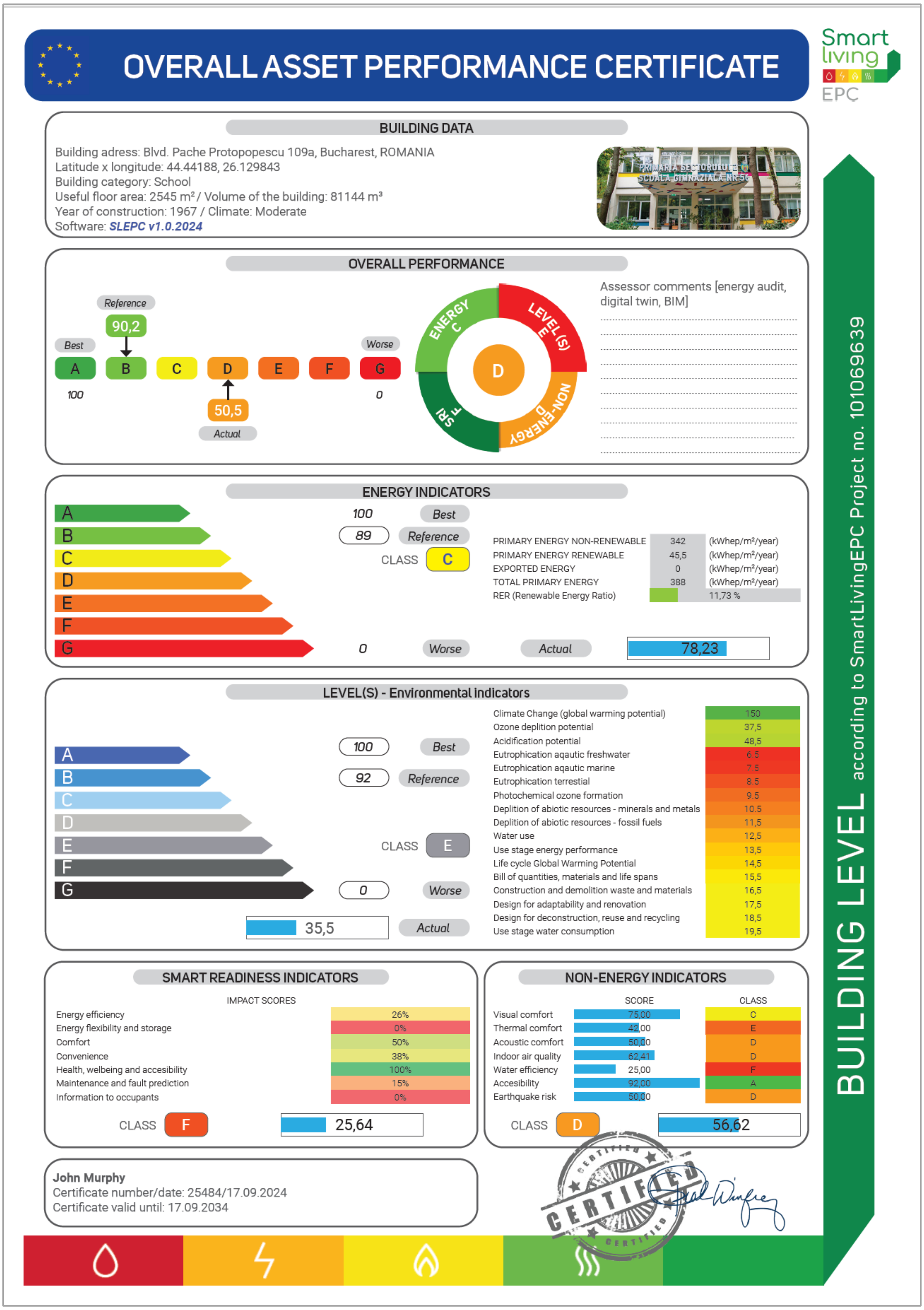


Figure 14: Proposed model for SLEPC certificate – building level

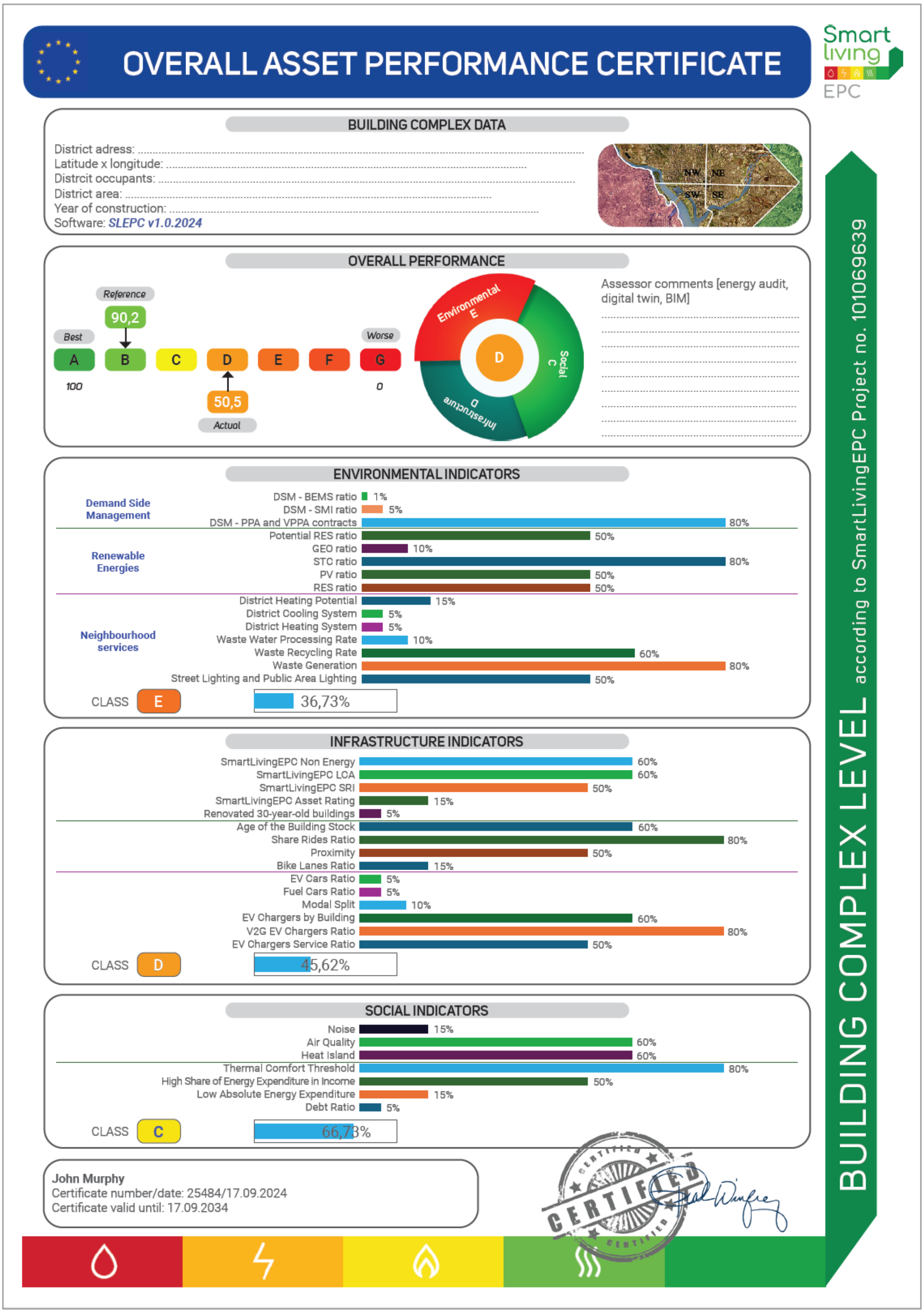


Figure 15: Proposed model for SLEPC certificate – building complex (district) level

The SLEPC Certificate is designed to serve as a comprehensive assessment tool for evaluating the performance of buildings. It provides a multifaceted evaluation that surpasses the scope of conventional energy certificates. The primary objective of this initiative is to enhance building performance and contribute to broader sustainability objectives by incorporating a diverse set of indicators and practical insights.

4.2 SmartLivingEPC labelling and performance classes

Buildings are categorized according to the performance classes A through G by the SmartLivingEPC (SLEPC) certificate, which offers a thorough assessment covering energy efficiency, non-energy indicators, Life Cycle Assessment (LCA) indicators, and smart readiness indicators. The SmartLivingEPC includes a score ranging from 0 to 100 in addition to a labeling and performance classification system represented by the letters A through G.

As concerns the energy indicators: Class A buildings are the most energy-efficient with low primary energy consumption and a large amount of renewable energy. The reduction in energy efficiency is significant as classes go down to G. Class G buildings exhibit extreme inefficiencies and outdated heating systems due to their high energy consumption, total reliance on non-renewable energy sources, lack of usage of renewable energy.

Non-Energy Indicators: Class A buildings use advanced materials and technologies to achieve peak performance, offering superior indoor air quality, thermal comfort, noise protection, visual comfort, accessibility, seismic risk and water efficiency. These qualities get worse with decreasing performance classes. Class G buildings have a severe need for upgrades because of their extremely poor indoor air quality, inefficient heating and cooling systems, and excessive water usage from obsolete plumbing.

Indicators of Life Cycle Assessment (LCA): Because they use sustainable materials and processes, Class A buildings have extremely little environmental effect, a very small carbon footprint, and excellent resource efficiency. The environmental impact sharply increases, as one approaches Class G. Class G buildings are extremely unsustainable because they have a very high Global Warming Potential (GWP), are inefficient with resources, and do not use any sustainable materials or techniques.

Smart Readiness Indicator: Class A buildings have state-of-the-art smart technology and highly effective building management systems installed for all-encompassing control and monitoring. The efficiency of management systems and the incorporation of smart technologies both sharply diminish when classes drop to G. Class G buildings are in dire need of upgrading because they have very antiquated management systems and no integration of smart technologies.

A more detailed understanding of the building's performance is offered by the number rating within each class, which directs owners toward certain areas that might be improved.

5 Conclusions and future research

Introduced inside the SmartLivingEPC project, this deliverable aims to provide a novel approach for asset rating computation. Building energy and environmental performance are evaluated comprehensively, combining ratings from technical audits, sustainability, energy efficiency, and smart readiness. SRI, energy and non-energy analysis, LCA, Levels(s), and building systems energy audits are among the WP2 tasks whose results are combined into a single, weighted grading system. Drawing on current urban sustainability frameworks and evaluation tools, the deliverable establishes the foundation for creating asset rating procedures at the building and neighborhood levels.

Neighborhood-scale energy-consuming services were classified and identified with great success, underscoring the significance of street lighting, urban forestry, drinking water supply, and transportation infrastructure. In order to give a basic grasp of assessing energy performance at the neighborhood level, the deliverable also looked at ideas like Energy Communities, Smart Grids, and Building Unit Interaction.

To guarantee its efficacy and relevance, the deliverable will be regularly updated and enhanced in response to new data, standards, and consortium partner inputs. The actual use of rating protocols for pilot buildings will receive special attention to guarantee sensitivity to various European nations and community kinds. The asset rating technique is strengthened, inclusive, and customized to the particular requirements and situations of users by adding thorough thoughts and examples at every stage.

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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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