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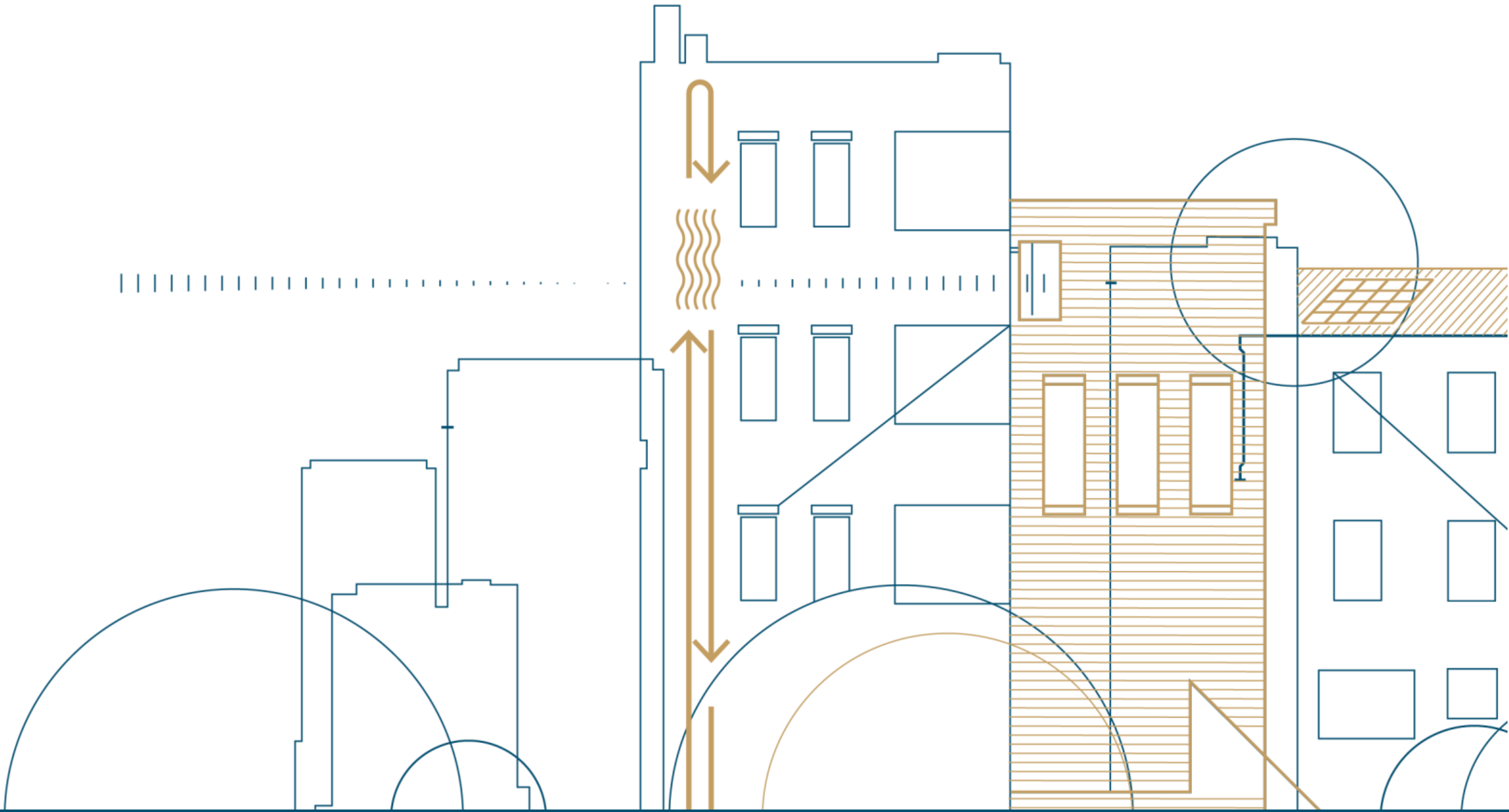

D3.1

LEVEL(s)-based MEL framework for REHOUSE RPs and demos

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EXECUTIVE SUMMARY

This document represents the Deliverable D3.1 “LEVEL(s)-based MEL framework for REHOUSE RPs and demos” developed within WP3 (Measurement, evaluation and learning methodology, impact assessment and platforms specifications). It presents firstly LEVEL(s) [1] framework that defines methods on how to assess key performance indicators (KPIs) for the evaluation of environmental performance of both renovations and new buildings. To complement this framework, an inventory of technical and social KPIs defined in other frameworks are presented:

- Regional/National/International regulations and standards;
- Scientific articles/ technical studies;
- Experience feedback from partners’ previous projects;
- Social frameworks.

The frameworks identified cover the countries of REHOUSE demonstration sites (Italy, Greece, Hungary and France) as well as include international context. Although the inventory of frameworks included an important number of regulations, studies and protocols, only the most complete and interesting ones have been incorporated in this deliverable. These are shown on the Figure 1.

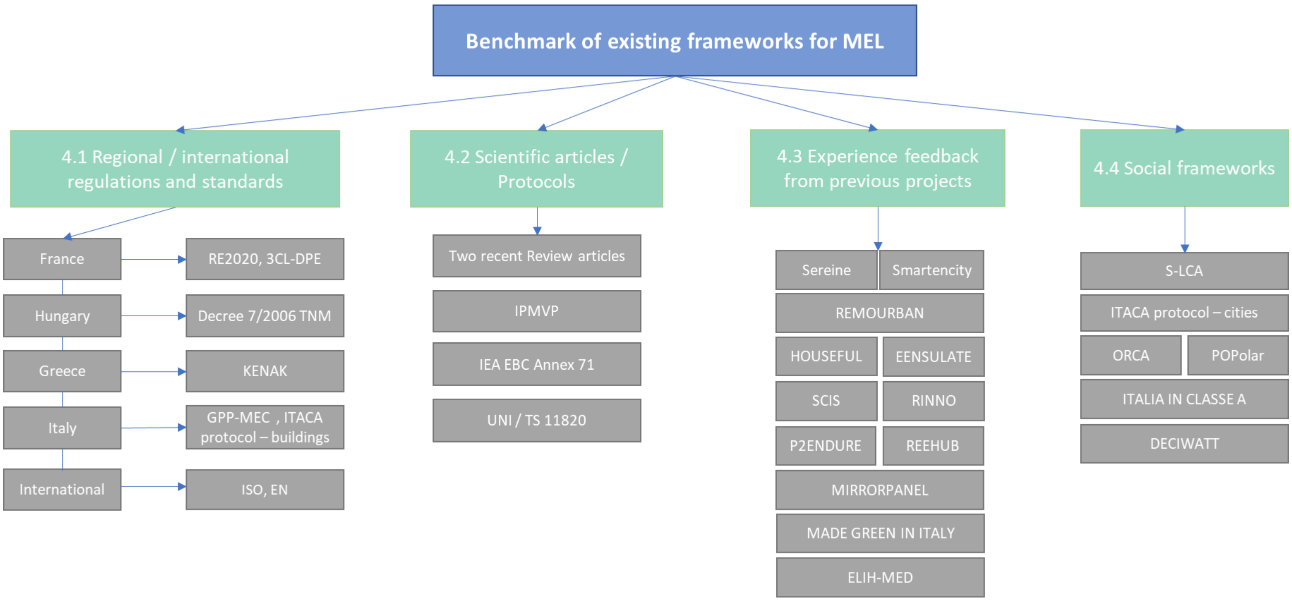

Figure 1. The existing MEL frameworks considered in the benchmark

Finally, a summary of KPIs from all these sources is established and classified in order to guide the further selection of the suitable KPIs for REHOUSE Renovation Packages and demonstration sites. To be in adequacy with the objectives of the REHOUSE project and the European LEVEL(s) framework the summary of KPIs is arranged by 3 criteria:

1. Scale. The KPIs are given at the scale of renovation packages, buildings and at the scale of territory/city.
2. Macro-objectives (MO) of the LEVEL(s) framework.
3. Category. The KPIs are classified by domain related to construction projects.

The links between these classifications are illustrated on the Figure 2. The buildings’ KPI are mainly based on the KPIs from the LEVEL(s) framework augmented with the results of the MEL inventory by REHOUSE project partners which together with Renovation Packages’ KPIs create a basis for the definition of the REHOUSE project KPIs in the task 3.2. The results of the MEL inventory by project partners allow also to identify some additional KPIs which are not considered by the LEVEL(s) framework.

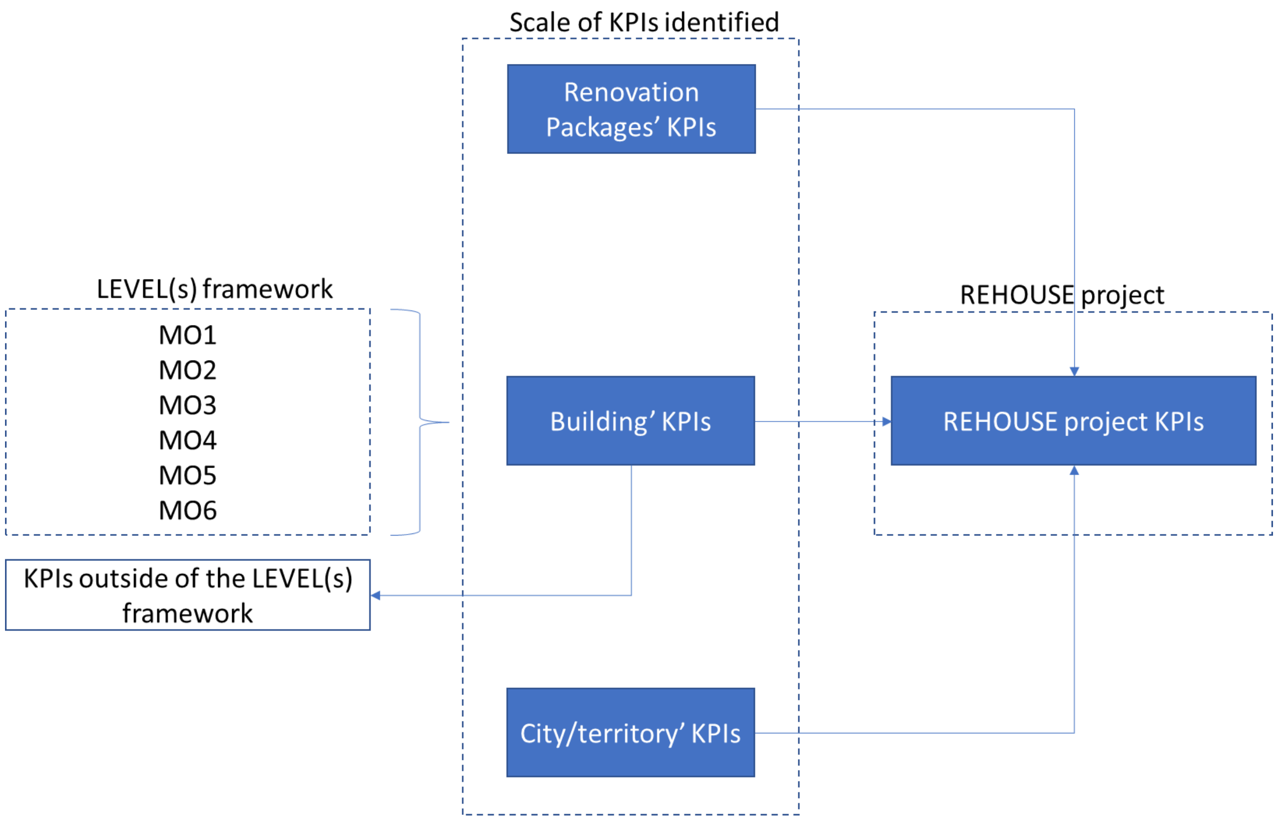

Figure 2. Relations between the three classifications of KPI

For the purposes of KPIs definition of the REHOUSE project in the Task 3.2 all the KPIs have been classified by the next categories:

- Building envelope. Here are included indicators related to thermal parameters of building walls and roof.
- Resource use. This category integrates indicators related to building energy and water consumption, as well as the amount of waste generated.
- Comfort conditions. It integrates indicators related to thermal, acoustic and visual comfort as well as the IAQ.
- Economics. It integrates indicators related to the cost dimension of construction process.
- Social/user's behaviour. This category includes indicators related to the evaluation of impact of building use on life of users and changes in users' behaviour inside or outside the building/dwelling they live.
- Environment and built environment. It integrates indicators related to greenhouse gas emissions of buildings in operational phase, as well as those associated to the outdoor environment of building or construction site.
- Resources re-use. This category includes indicators related to recycling and reuse of materials, wastes and other goods.

KEY WORDS: MEL framework, LEVEL(s) framework, Social frameworks, National regulations, EU benchmark, International standards, Renovation package, Key Performance Indicators, IPMVP, Environmental assessment, Sustainability, Energy poverty, SRI index.

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LIST OF ABBREVIATIONS

ACRONYM	DESCRIPTION
D	Deliverable
EC	European Commission
EPAH	Energy Poverty Advisory Hub
EPBD	Energy Performance of Buildings Directive
EPOV	Energy Poverty Observatory
EU	European Union
FTE	Full Time Equivalent
GHG	Greenhouse Gas
GIA	Gross Internal Area
IAQ	Indoor Air Quality
IPMVP	International Performance Measurement and Verification Protocol
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCC	Life Cycle Cost Assessment
LCIA	Life Cycle Impact Assessment
MEL	Monitoring, Evaluation and Learning
MO	Macro-Objective
MS	Member States
RP	Renovation Package
s-LCA	Social Life Cycle Assessment
SRI	Smart Readiness Indicator
WP	Work package
WT	Work task

1 INTRODUCTION

Each country in the EU has its proper regulations and methodologies for MEL. These regulations define the methods for assessment of building performances, as well as the associated KPIs. These methods and KPIs are very often different between the countries and regions of one country. The first framework aiming to unify the methodologies for MEL at the EU scale is the LEVEL(s) framework. This deliverable focuses to implement a benchmark of existing regulations and methodologies in each demo site' country and at the international scale in order to help the REHOUSE project partners to select the relevant MEL methodologies and KPIs and identify the KPIs outside of the LEVEL(s) framework scope.

1.1 PURPOSE AND SCOPE OF THE DOCUMENT

This deliverable aims to establish an inventory of existing frameworks and methodologies for MEL to complement LEVEL(s) framework which is the framework developed by the EC to improve the sustainability of buildings. This framework has been established to tackle issues such as climate change, resource scarcity, health and wellbeing and sustainable development. It defines a set of common indicators and metrics for measuring the environmental performance of both office and residential buildings during their full life-cycle.

The social impact of renovation process and packages is less described into the LEVEL(s) framework. In this deliverable this issue is handled through the presentation of social frameworks defined in relation with the objectives of WP1. This document will serve as a basis for the selection of the most appropriate KPIs for the REHOUSE project's RPs and demo sites in Task 3.2.

1.2 CONTRIBUTIONS OF PARTNERS

The following Table 1 depicts the main contributions from participant partners in the development of this deliverable.

Table 1 Contribution of partners

PARTICIPANT SHORT NAME	CONTRIBUTIONS
01 – CAR	European and international + Reviewer of D3.1
02 – CERTH	Benchmark for Greece and international
08 – ENEA	Benchmark for Italy and international
10 – RINA-C	Benchmark for Italy and international + Synthesis of KPIs and classification
11 – TERA	Benchmark for Italy and international
19 – CEA	Benchmark for France and international + Synthesis of KPIs and classification
21 – WOODS	Benchmark for Hungary and international
22 – PLATAN	Benchmark for Hungary and international
25 – NBK	Benchmark for France and international, WP3 Leader, T3.1 Leader, D3.1 Leader

1.3 RELATION TO OTHER ACTIVITIES IN THE PROJECT

The following table depicts the main relationship of this deliverable to other activities (or deliverables) developed within the REHOUSE Project and that should be considered along with this document for further understanding of its contents.

Table 2 Relation of this deliverable with other project activities

ACTIVITY (DELIVERABLE NUMBER)	DESCRIPTION
T1.3 & T1.4	Social KPIs are established in WP1 taking into account the local context
T3.2/ D3.2	KPIs for RPs and demos of REHOUSE are selected in T3.2 based on the results of D3.1 KPIs inventory

2 LEVEL(S) FRAMEWORK

2.1 DEFINITION & OBJECTIVES

LEVEL(s) is the first-ever European Commission framework aiming to improve the sustainability of buildings to assessing it throughout their life cycle. In this sense, LEVEL(s) has been designed to encourage users to think about the whole lifecycle of a building, providing a basis for quantifying, analysing and understanding the lifecycle. It goes beyond a building's service life and value by including elements that happened before and after this stage. LEVEL(s) provides a common language for stakeholders through a limited number of indicators. These indicators have been defined following the results of studies from more than 80 projects in 21 EU Member States.

As part of the REHOUSE project, one of the objectives of the WP3 is the definition of a Monitoring, Evaluation and Learning (MEL) methodology to assess the expected renovation packages and demo-sites performances. By using as basis the set of indicators defined by LEVEL(s), it is assured a convergence of the assessment with other projects and initiatives at EU level, providing a framework for possible comparison of results and a coherence on the process, as LEVEL(s) has been designed to ensure a minimum level of comparability between functionally equivalent buildings. Anyway, this means an adequate adherence of the users of this framework to some principles /rules, like using common units of measurement, parameters or assumptions, and applying the reference standards and methods specified by LEVEL(s).

As will be seen in further sections, apart from LEVEL(s), other frameworks, protocols or methodologies will be explored to complement the aspects already covered with others not fully comprised like social cohesion or energy poverty.

Level(s) framework provides a set of indicators and common metrics for measuring the sustainability performance of buildings along their life cycle, assessing the following four different areas: the building environmental performance, user's health and comfort aspects, life cycle cost (LCC) and value, and potential risks to future performance. The idea of this framework is to provide with a final valuable set of information and data which enables to understand, improve and optimize the sustainability performance of a building. This process of performance assessment involves gathering, handling and processing a wide range of data related to different aspects of the building and its life cycle as energy and water use, building elements and materials, building designs and structures, maintenance plans or indoor environment conditions.

The definition of the LEVEL(s) indicators is based on 6 macro-objectives, which describe what the strategic priorities should be for the contribution of buildings to EU and Member State policy objectives in areas such as energy, material use and waste, water and indoor air quality. In this way, buildings performance can be measured seeking to contribute to the EU policies and objectives compliance.

The six mentioned macro-objectives are defined in the following way:

- MO1 – Greenhouse gas and air pollutant emissions along a building's life cycle: Minimize the total greenhouse gas emissions along a building's life cycle, from cradle to grave, with a focus on emissions from building operational energy use and embodied energy.
- MO2 – Resource efficient and circular material life cycles: Optimize the building design, engineering and form in order to support lean and circular flows, extend long-term material utility and reduce significant environmental impacts.
- MO3 –Efficient use of water resources: Make efficient use of water resources, particularly in areas of identified long-term or projected water stress.
- MO4 –Healthy and comfortable spaces: Create buildings that are comfortable, attractive and productive to live and work in, and which protect human health.
- MO5 –Adaptation and resilience to climate change: Futureproof building performance against projected future changes in the climate, in order to protect occupier health and comfort and to minimize long-term risks to property values and investments.
- MO6 –Optimized life cycle cost and value: Optimize the life cycle cost and value of buildings to reflect the potential for long-term performance improvement, inclusive of acquisition, operation, maintenance, refurbishment, disposal and end of life.

REHOUSE is thoroughly aligned with Level(s) principles. Table 3 shows the links between some of the Level(s) Macro objectives and REHOUSE Expected Outcomes.

Table 3 Level (s) Macro objective and Rehouse expected outcome associated

Level(s) Macro objective	REHOUSE Expected Outcome associated
 1 Green house gas emissions along a building's life cycle	**EO2.** Improvement of insulation and air-tightness compared to standard renovation solutions. **E04.** Improved affordability of sustainable renovation and RES systems in buildings, in particular for households experiencing energy poverty issues. **EO5.** Reduction of embodied energy and CO2 of renovation, and emission of air pollutants over the life cycle. **EO6.** Increased deployment of built-in renewable energy generation solutions for on-site multipurpose.
 2 Resource efficient + circular material	**EO1.** Increased scale and productivity in the renovation process. **EO5.** Reduction of embodied energy and CO2 of renovation, and emission of air pollutants over the life cycle. **EO7.** Increased share of reused and/or recycled and/or bio-sourced construction materials used in building renovation to contribute to circular economy. **EO8.** Faster uptake of standards or certification of reused and/or recycled construction materials/products.
 4 Healthy + comfortable spaces	**EO2.** Improvement of insulation and air-tightness compared to standard renovation solutions. **EO3.** Demonstrated improvement of indoor environment and user comfort and satisfaction, as well as accessibility, increasing attractiveness of renovation for building owners and users.

Level(s) Macro objective	REHOUSE Expected Outcome associated
 6 Optimised life cycle cost and value	**EO3.** Demonstrated improvement of indoor environment and user comfort and satisfaction, as well as accessibility, increasing attractiveness of renovation for building owners and users.

2.2 LEVEL(S) KPIS

Level(s) owes its name to the fact that it proposed three different levels of accuracy for input data sources and data processing (related to the user's expertise), going from Level 1 (Conceptual design) corresponding to estimative and reference figures to Level 3 (As-built and in-use) corresponding to monitoring and values obtained from detailed assessment. The three levels of the common framework provide a choice as to how advanced the reporting on sustainability for the project will be, and they represent the following stages in the execution of a building project:

Level 1. The conceptual design for the building project – the simplest level as it entails early stage qualitative assessments of the basis for the conceptual design and reporting on the concepts that have or are intended to be applied.

Level 2. The detailed design and construction performance of the building – an intermediate level as it entails the quantitative assessment of the designed performance and monitoring of the construction according to standardised units and methods.

Level 3. The as-built and in-use performance of how the building performs after completion and handover to the client – the most advanced level as it entails the monitoring and surveying of activity both on the construction site and of the completed building and its first occupants.

The basic idea is that the levels represent a professional journey from the initial concept through design, construction and then, after handover, to the reality of the completed building. Progression up the levels also represents an increase in the accuracy and reliability of the reporting – the higher the level, the closer the reported results will be to providing you with data that reflects the performance of the building as-built and in-use.

In REHOUSE the three levels are covered as demo-sites goes from conceptual design, going through the detailed design and construction until the commissioning and occupation/use.

Within LEVEL(s) structure, and bearing in mind the mentioned macro-objectives, LEVEL(s) defines 16 core indicators. Each indicator has been selected to measure the performance and contribution of a building towards a specific macro-objective. An overview of the indicators and their units of measurement is provided in Figure 3 below.

Macro-objective	Indicator	Unit of measurement
1: Greenhouse gas and air pollutant emissions along a building's life cycle	1.1 Use stage energy performance	kilowatt hours per square metre per year ($kWh/m^2/yr$)
	1.2 Life cycle Global Warming Potential	kg CO_2 equivalents per square metre per year (kg CO_2 eq./m^2/yr
2. Resource efficient and circular material life cycles	2.1 Bill of quantities, materials and lifespans	Unit quantities, mass and years
	2.2 Construction & demolition waste and materials	kg of waste and materials per m^2 total useful floor area
	2.3 Design for adaptability and renovation	Adaptability score
	2.4 Design for deconstruction, reuse and recycling	Deconstruction score
3. Efficient use of water resources	3.1 Use stage water consumption	m^3/yr of water per occupant
4. Healthy and comfortable spaces	4.1 Indoor air quality	Parameters for ventilation, CO2 and humidity Target list of pollutants: TVOC, formaldehyde, CMR VOC, LCI ratio, mould, benzene, particulates, radon
	4.2 Time outside of thermal comfort range	% of the time out of range during the heating and cooling seasons
	4.3 Lighting and visual comfort	Level 1 checklist
	4.4 Acoustics and protection against noise	Level 1 checklist
5. Adaptation and resilience to climate change	5.1 Protection of occupier health and thermal comfort	Projected % time out of range in the years 2030 and 2050 (see also indicator 4.2)
	5.2 Increased risk of extreme weather events	Level 1 checklist (under development)
	5.3 Increased risk of flood events	Level 1 checklist (under development)
6. Optimised life cycle cost and value	6.1 Life cycle costs	Euros per square metre per year (€/m2/yr)
	6.2 Value creation and risk exposure	Level 1 checklist

Figure 3: Overview of the LEVEL(s) indicators by macro-objectives

The majority of the core indicators have a single unit of measurement. However, there are some important exceptions, for which performance must be assessed and reported in a different way:

- Composite indicators (1.2, 2.2, 4.1): These indicators are more complex and difficult to reduce to a single unit of measurement. Instead they consist of several related units of measurement that must be read together to understand a building's performance.
- Qualitative assessments (4.3, 4.4, 5.2, 5.3, 6.2) These indicators do not currently have an agreed quantitative unit or units of measurement, so instead the results of a qualitative assessment can be reported.
- Information reporting (2.1): This indicator is designed to encourage users to handle and process specific items of data about their building as an aid to life cycle thinking.

3 BENCHMARK OF EXISTING FRAMEWORKS FOR MEL

In this section, a benchmark of existing frameworks for MEL identified by REHOUSE Project is presented. This inventory lists about thirty references classified according to the diagram shown on Figure 4. This presentation takes into account the local regulations of the four countries represented in this project, the ISO standards describing the principles of the frameworks and the methods associated with the calculation of certain KPIs, different approaches coming from projects in which the project partners have participated, as well as frameworks dealing with the social aspect in order to complement Level(s).

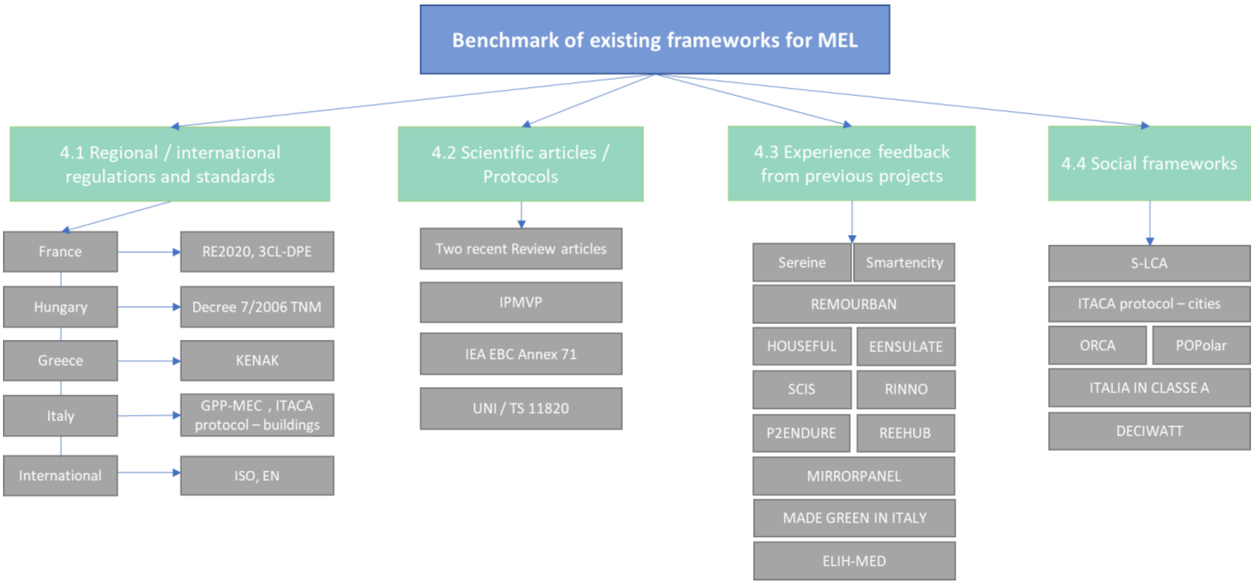

Figure 4 Overview of the frameworks and their classification presented in this section

3.1 REGIONAL/NATIONAL/INTERNATIONAL REGULATIONS AND STANDARDS

The regional regulations and standards concern the four European countries of the demo-sites: France, Hungary, Greece and Italy. For each country, the main regulations and standards have been reported. In addition, useful European and international standards for the evaluation of sustainable buildings are presented in this sub-section. It should be noted that, for reasons of clarity, the list of KPIs and the reference for calculation method are specified in this section only for France, Hungary and Greece. For the case of Italy, the regulations references are described also in this sub-section, but the list of KPIs is reported in the Annex I: Regional/ National/ International regulations and standards.

3.1.1 FRANCE

French Environmental regulation: RE2020

Description and objectives:

In 2020, France moved from a thermal regulation to an environmental regulation, the RE2020, more ambitious and demanding for the construction industry. Its objective is to continue improving the energy performance and comfort of buildings, while reducing their carbon impact. It is based on three main axes:

- Continuing to improve the energy performance and reduce the consumption of new buildings.
- Reduce the impact of new buildings on the climate by taking into account all of the building's emissions over its life cycle, from the construction phase to the end of its life (construction materials, equipment), including the operating phase (heating, domestic hot water, air conditioning, lighting, etc.), via a life cycle analysis.
- Enable occupants to live and work in a place that is adapted to future climatic conditions by pursuing the objective of comfort in summer. Buildings will have to be more resistant to heat waves, which will be more frequent and intense due to climate change.

The RE2020 is based on a gradual transformation of construction techniques, industrial sectors and energy solutions, in order to control construction costs and ensure that professionals become more skilled. Indeed, the French regulation describes six KPIs classified in three categories Energy, Carbone and summer Comfort.

List of KPIs:

Categories	KPIs (units)	Description
Energy	Bbio (points)	Bioclimatic needs
	Cep (kWhep/(m².an))	Total primary energy consumption
	Cep,nr (kWhep/(m².an))	Non-renewable primary energy consumption
Carbone	$Ic_{énergie}$ (kg eq. CO_2/m²)	Impact on climate change associated with primary energy consumption
	$Ic_{construction}$ (kg eq. CO_2/m²)	Impact on change climate change associated to "components" + "construction site"
Summer Comfort	DH (°C.h)	Summer Degree-hour of discomfort

Reference for calculation method:

Ministère de la transition écologique, Décret no 2021-1004 du 29 juillet 2021 relatif aux exigences de performance énergétique et environnementale des constructions de bâtiments en France métropolitaine. Journal officiel, N°0176 du 31/07/2021, Texte 56 sur 149.

3CL-DPE

Description and objectives:

Energy Performance Diagnosis (DPE) is a mandatory rating survey in France that provides information on the energy performance of a dwelling or building by assessing its energy consumption and its impact in terms of greenhouse gas emissions.

The objectives are:

- To inform future buyer or tenant about the building energy performance.
- To compare buildings objectively regarding the energy performance.
- To identify buildings that need to be renovated and to give indicators for the renovation.

DPE are conducted by technicians who must be certified by an accredited certification body, to prove that they have the knowledge, experience, and skills to perform DPE in buildings.

List of KPIs:

Categories	KPIs (units)	Description
Energy	Cep (kWhep/m².year)	Primary energy consumption
Carbone	EGES (kg eq CO_2/m².year)	Amount of greenhouse gases emitted
Costs	Annual energy cost estimation (€/year)	Annual consumption expenditure of energy consumed or estimated for each category of equipment according to a conventional calculation method
Comfort	Summer comfort (rating)	Capacity of the dwelling (or part of it) to provide thermal comfort in summer

Reference for calculation method:

The DPE gives a label based on these values. It follows calculation methods that have been defined in the following decree: *Ministère de la transition écologique, Arrêté du 8 octobre 2021b modifiant la méthode de calcul et les modalités d'établissement du diagnostic de performance énergétique. Journal officiel n°0240 du 14/10/2021*

3.1.2 HUNGARY

Decree 7/2006 TNM

Description and objectives:

The scope of this regulation covers the buildings and building elements specified in the government decree on the certification of the energy characteristics of newly built buildings. The decree defines mechanisms and criteria for determining buildings' energy performance.

The decree elaborates on questions and surrounding conditions to be taken into account when considering the integration of renewable energy sources in new buildings. An obligation is laid out to satisfy at least 25% of the buildings' energy needs with RES, which is applicable for buildings that will be operationalized after 31 December 2020 and buildings operationalized by authorities after 31 December 2018 (§6 (2) Decree No. 7/2006 and Appendix 6. Decree No. 7/2006).

According to the calculation method every building will be classified based on the minimal energy demand from the worst class "JJ" to the best class "AA++". In case of new built buildings, they have to reach a minimum CC level, but it is recommended the highest class.

The calculation method takes into consideration:

- Elements of the boundary structures or building technical systems.
- Technical equipment for room heating, room cooling, ventilation, domestic hot water supply.
- Ratio of building's surface volume ratio and provides requirements for the current ratio.

The decree 7/2006 TNM should be taken into consideration in cases of renovation affecting at least 25% of the total surface of buildings. Which is the case of Hungarian demo site where the full wall and window surfaces are planned to be renovated.

List of KPIs:

Categories	KPIs (units)	Description
Building envelope	KPI02 (W/(m²K))	Insulation improvement against standards
Energy	KPI12 (kWh/m²)	Expected annual energy demand

Reference for calculation method:

The mentioned decree contains annexes in which the methodology is detailed written and the necessary data is provided.

3.1.3 GREECE

Greek regulation for the Energy Efficiency of Buildings: KENAK

Description and objectives:

The National Energy Performance Regulation of Buildings (KENAK) is the Greek adaptation of the European Energy Performance of Buildings Directive (EPBD). It includes the methodology for the calculation of the energy performance of buildings. KENAK is accompanied by the following technical directives containing detailed guidelines on the process and the parameters of the calculation:

1. TOTEE 20701-1/2017: "*Detailed national parameter specifications for the calculation of the energy efficiency of buildings and the issuance of the energy efficiency certificate (EPC)*",
2. TOTEE 20701-2/2017: "*Thermophysical properties of building materials and control of the thermal insulation adequacy of buildings*",
3. TOTEE 20701-3/2010: "*Climatic data of Greek regions*",
4. TOTEE 20701-4/2017: "*Guidelines and report forms for energy inspections of buildings, heating systems and air conditioning systems*",
5. TOTEE 20701-5/2017: "*Cogeneration of Electricity, Heat and Cooling: Installations in Buildings*".

The defined parameters include, but are not limited to envelope elements, shading, indoor lighting, air quality, HVAC and DHW systems, RES utilization, etc., and how they should be taken into account in the calculations. The proposed methodology is used both in the energy efficiency study at the design stage of a new building and in the energy inspection of both new and existing buildings. Minimum requirements for energy performance of buildings and building elements are set according to the specific climatic zone where the buildings belong. In terms of deep renovation, the existing buildings must reach the B+ Class of the National Energy Performance Regulation (KENAK), while for newly constructed buildings, an A energy class is expected, following the EU guidelines for near zero energy buildings (nZEB) from 2021 onward.

The main objective of KENAK is to provide a common methodology for calculating the energy performance of buildings in Greece, as well as the necessary supporting material. The Energy Performance Certificate is mandatory for any new or deep renovated building (in Greece) and for each building which was sold or rented after 2010.

List of KPIs:

Categories	KPIs (units)	Description
Energy	Energy performance (kWh/m2/yr)	Annual energy consumption (per built floor area)
Indoor environment	Indoor air quality (m^3/h/person or $m^3/h/m^2$)	Measured by the fresh air imported into the building. Suggested values are given depending on the use of the space and they are utilized for the calculation of the final energy performance. If the measured values match the provided guidelines, the KPI is considered achieved.
Comfort	Thermal comfort range (yes/no)	Thermal comfort is considered achieved, when the indoor temperature is within the provided range according to the use of the building.

Categories	KPIs (units)	Description
	Lighting and visual comfort (lx)	A minimum amount of lighting is recommended according to the use of the building, while aiming to keep the installed power of luminaires per unit of built area below a provided threshold.

Reference for calculation method:

Technical Directive 20701-1/2017. (2017). Detailed national specifications of parameters for calculating the energy efficiency of buildings and the issue of the energy performance certificate. Official Gazette of the Hellenic Republic [3].

3.1.4 ITALY

ITALIAN GPP COMPULSORY MINIMUM ENVIRONMENTAL CRITERIA (MEC)

Description and objectives:

The GPP (Green Public Procurement, i.e., Green Purchasing in the public administration) is an environmental policy instrument which intends to favour the development of a market of products and services with a reduced environmental impact, contributing, in a decisive way, to the achievement of the objectives of the main European strategies such as the efficient use of resources or the Circular Economy. It was introduced in Italy in 2008 with the National GPP Action Plan which provided for the adoption, with subsequent ministerial decrees, of the Minimum Environmental Criteria (MEC or CAM in Italian) for each category of products, services and works purchased or entrusted by the public administration.

The first version of the GPP MEC for buildings was approved in 2015 (Ministerial Decree 24/12/2015) but the Criteria are updated every 2/3 years in order to make them compliant with the increasingly stricter national legislation on energy efficiency in the building sector.

The MEC in the building sector apply to all construction works governed by the Public Contracts Code, the objective is to provide a set of mandatory criteria/requirements for a building's performance (in terms of environmental sustainability, energy efficiency and circularity) for new and renovated buildings, including specifications for the building materials valid for renovations, and technical requirements for buildings sites. Two sets of the criteria (and specifically the "Technical specifications for construction products" and "Technical and design specifications for the construction site") are mandatory for all types of renovations in publicly owned buildings in Italy. GPP MEC must be implemented throughout the design and construction phases and applied into:

- Tenders for design services (all design stages).
- Tenders for construction works.
- Tenders for integrated design and construction works.

MEC includes requirements not just for the building itself but also for designers' and contractors' skills and qualification in environmental issues.

List of KPIs and Reference for calculation method:

As mentioned at the beginning of this section, for clarity reasons the identified KPIs and their categories are listed in Annex I: Regional/ National/ International regulations and standards. The information about the calculation method of each KPI can be found in the GPP website [4].

ITACA Protocol

The Itaca Protocol is a tool for assessing the level of energy and environmental sustainability of buildings. The Protocol makes it possible to verify the performance of a building in reference to building consumption, energy efficiency, impact on the environment and impact on human health.

The Itaca Protocol has different uses and purposes in relation to its different use: it is a design support tool for professionals, a control and guidance tool for the public administration, supports the choice of consumers and enhances investments for financial operators.

The ITACA Protocol was born in the early 2000s and was created by the ITACA working group with the technical-scientific support of iiSBE Italia and ITC-CNR. The ITACA Protocol is derived from the SBTool international evaluation model, developed as part of the Green Building Challenge research process, and contextualized to the Italian territory in relation to the reference legislation and its environmental characteristics.

The principles on which the tool is based are the identification of criteria for measuring the environmental performance of the building in question, the definition of reference performances (baselines) with which to compare those of the building for the purpose of assigning a score, the "weighing" of the criteria that determine their greater and lesser importance, the final score which defines the degree of improvement of the overall performance compared to the standard reference level.

The evolution of the Protocol at national level has led to the drafting of a specific UNI reference practice. The current version of the ITACA Protocol is the Reference Practice UNI/PdR 13:2019. The previous Reference Practice UNI/PdR 13:2015 was replaced to adapt the tool to the introduction of the CAM.

The reference practice applies to residential buildings and non-residential, newly built or subject to major renovations, to the building and not to the individual unit. The reference practice applies only to executive level projects. Lower design levels do not allow verification of the evaluation criteria indicators.

List of KPIs & Reference for calculation method:

The identified KPIs and their categories are listed in Annex 1. The methods for calculating each KPI are indicated in the Reference Practice documents UNI/PdR 13:2019 structured as follows:

- UNI/PdR 13.0 Environmental sustainability in buildings - Operational tools for sustainability assessment - General framework and methodological principles;
- UNI/PdR 13.1 Environmental sustainability in buildings - Operational tools for sustainability assessment – Residential buildings;
- UNI/PdR 13.2 Environmental sustainability in buildings - Operational tools for sustainability assessment – Non-residential buildings.

Sections 1 and 2 of UNI/PdR 13 are divided into "criteria sheets" containing the criteria for the evaluation of the building and pertinent areas.

3.1.5 INTERNATIONAL

This sub-section collects a list of European and international standards that are aligned with the scope of the REHOUSE project. The Table 4 below lists the ISOs and EN identified of interest for the REHOUSE framework:

Table 4 List of International (ISO) & European (EN) standards identified in REHOUSE Project

Standard number	Title
ISO 14040:2006	Environmental management – Life cycle assessment – Principles and frameworks
ISO 14044:2006	Environmental management – Life cycle assessment – Requirements and guidelines
ISO 15686-5:2017	Buildings and constructed assets – Service life planning – Life cycle costing
ISO/CD 14075	Principles and framework for social life cycle assessment
ISO 7730:2005	Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria
ISO 16813:2006	Building environment design – Indoor environment – General principles
ISO 50006:2014	Energy management systems – Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) – General principles and guidance
ISO 14067:2018	Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification
ISO 52120-1:2021	Energy performance of buildings – Contribution of building automation, controls and building management – Part 1: General framework and procedures
ISO 21931-1:2022	Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 1: Buildings
ISO 20887:2020	Sustainability in buildings and civil engineering works — Design for disassembly and adaptability — Principles, requirements and guidance
ISO 21678:2020	Sustainability in buildings and civil engineering works — Indicators and benchmarks — Principles, requirements and guidelines
ISO 15392:2019	Sustainability in buildings and civil engineering works — General principles
ISO 16745-2:2017	Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 1: Calculation, reporting and communication
ISO 21929-1:2011	Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators and a core set of indicators for buildings
ISO 22057:2022	Sustainability in buildings and civil engineering works — Data templates for the use of environmental product declarations (EPDs) for construction products in building information modelling (BIM)
ISO 17741:2016	General technical rules for measurement, calculation and verification of energy savings of projects
EN 17267:2019	Energy measurement and monitoring plan. Design and implementation. Principles for energy data collection
EN 17472:2022	Sustainability of construction works - Sustainability assessment of civil engineering works - Calculation methods
EN 15643:2021	Sustainability of construction works - Framework for assessment of buildings and civil engineering works
EN 15804:2012+A2:2019	Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products
CEN/TR 17005:2016	Sustainability of construction works - Additional environmental impact categories and indicators - Background information and possibilities - Evaluation of the possibility of adding environmental impact categories and related indicators and calculation methods for the assessment of the environmental performance of buildings

Standard number	Title
EN 16627:2015	Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods
UNE-EN 16309+A1:2014	Sustainability of construction works - Assessment of social performance of buildings - Calculation methodology
EN 15978:2011	Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method

The detailed description of these standards is presented in Annex I: Regional/ National/ International regulations and standards. Furthermore, two labels for the evaluation of the buildings sustainability are reported as international frameworks here below:

BREEAM (Building Research Establishment Environmental Assessment Method), first published by the Building Research Establishment (BRE) from UK in 1990, is maybe the world's longest established method of assessing, rating, and certifying the sustainability of buildings. It is an international standard, but also exist country specific schemes, adapted for local conditions for UK, Germany, Netherlands, Norway, Spain, Sweden and Austria. It has technical standards for new construction, refurbishment and fit-out, In-use (operational performance), Communities (new communities and regeneration projects), Infrastructure, and Quality Mark. The assessment is undertaken by independent licensed assessors using scientifically-based sustainability metrics and indices which cover a range of environmental issues. BREEAM sets standards for buildings, communities and infrastructure in a very broad range of sustainability issues in nine categories: Energy, Waste, Water, Materials, Health and Wellbeing, Transport, Pollution, Land Use & Ecology, and Management. Buildings are rated and certified on a scale of 'Pass', 'Good', 'Very Good', 'Excellent' and 'Outstanding'. There is a specific technical standard for Refurbishment and Fit-Out that provides a framework to deliver projects to a high performing and sustainable standard, support commercial success and create positive environmental and social impact. It can be used to assess refurbishment of the external envelope, structure, core services, local services, and interior design of existing buildings.

LEED is a certification that focuses on environmental impact and sustainability. It's a green building certification program developed the U.S. Green Building Council (USGBC), including a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighbourhoods, directed to help building owners and operators to be environmentally responsible and use resources efficiently. To achieve LEED certification, a project earns points by adhering to prerequisites and credits that address carbon, energy, water, waste, transportation, materials, health and indoor environmental quality. LEED consists of credits which earn points in several categories including: Integrative Process, Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation, and Regional Priority. One hundred and ten points are available across these categories with mandatory prerequisites such as minimum energy and water-use reduction, recycling collection, and tobacco smoke control. Within each category are credits that pertain to specific strategies for sustainability, such as the use of low-emitting products, reduced water consumption, energy efficiency, access to public transportation, recycled content, renewable energy, and daylighting.

The types of indexes evaluated are the following [5]:

1. Sustainability of the Site: analyses the building-context relationship with the aim of limiting the impact of construction activities in favour of construction methods and techniques that respect the environmental balance.
2. Water Management: examines the environmental issues related to hydrogeological aspects and promotes the intelligent use of water and the recovery of meteoric ones.
3. Energy and Atmosphere: supports the use of renewable energy sources and the enhancement of the energy performance of buildings.
4. Materials and Resources: selects environmentally friendly materials, promotes sustainable techniques and methods in favour of reducing the environmental impact due to transport.
5. Internal environmental quality: deals with the psycho-physical well-being inside the rooms, checking air quality, energy consumption and healthiness.
6. Innovation in Design: identifies new solutions consistent with sustainable design.
7. Regional Priority: attention is paid to the specificity of the site in which the building under examination is located, encouraging the designers to consider its individual characteristics.

3.2 SCIENTIFIC ARTICLES/ PROTOCOLS AND TECHNICAL STUDIES

This section deals with relevant scientific articles, international/local protocols and technical specifications/studies. Two recent review articles have been identified that present a state of the art of KPIs for the evaluation of sustainable building renovation and the methodology followed for the selection of the most appropriate indicators. In addition, two essential international protocols (for the evaluation of building energy performance: IPMVP, IEA EBC ANNEX 71) and a technical specification (for the evaluation of circular economy indicators) have been identified and described. For each of these frameworks, the list of indicators is listed in the Annex II: Scientific articles/ Protocols and Technical studies.

Key performance indicators for holistic evaluation of building retrofits: Systematic literature review and focus group study

This is a review article in which the authors conducted an extensive search to identify the most appropriate KPIs for building renovation. After grouping the indicators into different categories, a focus group study was conducted with experts in the field of facilities management to shortlist the most useful KPIs for the development of the aforementioned performance evaluation method. These KPIs have been grouped into four categories: Environmental, Economic, Health & Safety and User's Perspective.

Key performance indicators (KPIs) approach in buildings renovation for the sustainability of the built environment: A Review

This review article provides a brief foreword regarding the state of the art in building renovation projects, as well as the suitability of the application of the KPIs approach for the assessment of sustainability level in such projects and analyses the results of the literature review. The list of categories and sub-categories identified in this article is listed in Annex II: Scientific articles/ Protocols and Technical studies.

IEA EBC Annex 71: Building energy performance assessment based on in-situ measurements

The Annex 71 is one of 86 projects of the IEA Energy and Building Communities (IEA EBC) that aims to develop a replicable methodology to characterize and assess the actual energy performance of buildings starting from on board monitored data of in-use residential buildings. The project focuses on the Heat Transfer Coefficient (HTC) as the main Key Performance Indicator for building performance assessment. The project has identified several definitions of this KPI, which differ according to the European countries, and several experimental and/or numerical methods allowing its evaluation. For each method, the necessary equipment, recommended experience, required time and effort, and achievable accuracy were described.

This technical specification takes into account the environmental aspects, social and economic, considered through a set of 71 suitable indicators. There are seven categories of indicators, which include: Material resources and components, energy and water resources, waste and emissions, logistics, product/service, human resources/assets/policies and sustainability.

IPMVP protocol

IPMVP stands for International Performance Measurement and Verification Protocol. It is a standardized protocol for quantifying energy and water savings resulting from building energy efficiency projects or other types of energy conservation measures (ECM).

The IPMVP protocol provides a framework for energy efficiency professionals (building owners, energy managers and others) to measure and verify the actual energy savings achieved from ECMs, and it provides guidelines for establishing a consistent and transparent process for measurement and verification.

The energy savings are generally determined by comparing measured energy use before and after implementation of ECM:

Energy Savings = Baseline year Energy Use - Post-Retrofit Energy Use ± Adjustments,

But in the real situations some parts of this equation above are often not available or corrupted. To resolve this the IPMVP defines four main options, which range from basic data analysis to more complex methods that involve statistical analysis.

The four options of IPMVP are:

- Option A: This is the simplest option, which involves comparing energy consumption before and after the implementation of one energy conservation measure.
- Option B: This option involves a more detailed analysis to estimate the energy savings resulting from the project. Savings are determined by field measurement of the energy use of the systems to which the ECM was applied, separate from the energy use of the rest of the building or facility.
- Option C: This option involves a rigorous statistical analysis, comparing the energy consumption of a whole building before and after implementing the ECMs by considering the adjustments needed through mathematical models to have a faire comparison. It is used to estimate energy savings from several ECMs applied during a global building renovation process.
- Option D: This is the most complex option, which involves a detailed engineering analysis of the ECM and its impact on energy consumption, using energy modelling and simulation. It is used mainly when there is no of measurable baseline data.

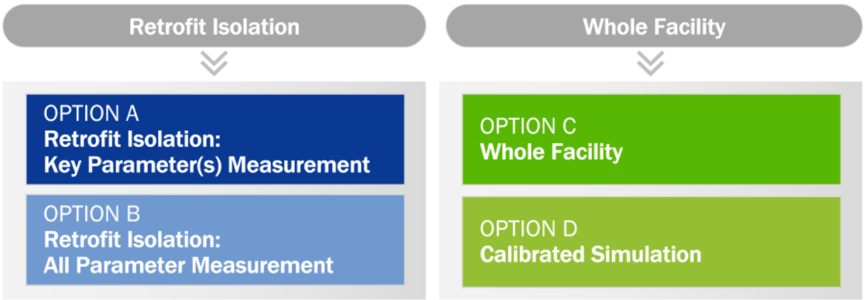

Figure 5. The four options of the IPMVP protocol [6]

Overall, IPMVP is a widely used protocol for quantifying energy savings resulting from building energy efficiency projects, and it can help building owners and energy managers to better understand the impact of their ECMs. By providing a standardized and transparent process for measuring and verifying energy savings, the IPMVP protocol helps to build confidence in the effectiveness of ECMs and supports the development of sustainable energy policies.

<u>SRI Score</u>

The EC established a methodology called "Smart Readiness Indicator" (SRI) as an instrument for rating the smart readiness of buildings. The aim of the SRI is to raise awareness of the benefits of smarter building technologies and functionalities and make their added value more tangible for building users, owners, tenants, and smart service providers.

This voluntary common EU scheme assess the technological readiness of buildings through the readiness to 3 key functionalities [7]:

- Interact with their occupants and adapt in response to their needs.
- Interact with connected energy grids and adapt the building's electricity demand in relation to these grids.
- Operate more efficiently and maintain energy efficiency performance during the building operation.

The SRI methodology builds on the assessment of the smart ready services present in a building. Services are enabled by (a combination of) smart ready technologies, but are defined in a technology neutral way, e.g. 'provision of temperature control in a room'. The smart ready services are structured within nine domains: heating, cooling, domestic hot water, controlled ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging and monitoring and control.

A smart ready service can provide several impacts to the building, its users, and the energy grid. In the SRI approach, a set of seven impact criteria is evaluated. These impact criteria are:

- Energy savings on site. This impact category refers to the impacts of the smart ready services on energy saving capabilities. It is not the whole energy performance of buildings that is considered, but only the contribution made to this by smart ready technologies, e.g. resulting from better control of room temperature settings.
- Flexibility for the grid and storage. This impact category refers to the impacts of services on the energy flexibility potential of the building. The study proposes to not solely focus on electricity grids, but also include flexibility offered to district heating and cooling grids.
- Comfort. This impact category refers to the impacts of services on occupant's comfort. Comfort refers to conscious and unconscious perception of the physical environment, including thermal comfort, acoustic comfort, and visual performance (e.g. provision of

sufficient lighting levels without glare).

- Convenience. This impact category refers to the impacts of services on convenience for occupants, i.e. the extent to which services “make life easier” for the occupant, e.g. TBS requiring fewer manual interactions.
- Well-being and health. This impact category refers to the impacts of services on the well-being and health of occupants. For instance, smarter controls can deliver an improved indoor air quality compared to traditional controls, thus raising occupants’ well-being, with a commensurate impact on their health.
- Maintenance and fault prediction. Automated fault detection and diagnosis has the potential to significantly improve maintenance and operation of technical building systems. It also has potential impacts on the energy performance of the technical building systems by detecting and diagnosing inefficient operation.
- Information to occupants. This impact category refers to the impacts of services on the provision of information on building operation to occupants.

	Overall SRI score (%) + SRI class						
	%		%				%
	Optimise energy efficiency and overall in-use performance		Adapt its operation to the needs of the occupant				Adapt to signals from the grid (energy flexibility)
	%	%	%	%	%	%	%
	Energy efficiency	Maintenance and fault prediction	Comfort	Convenience	Health, well-being and accessibility	Information to occupants	Energy flexibility and storage
Heating	%	%	%	%	%	%	%
Cooling	%	%	%	%	%	%	%
Domestic hot water	%	%	%	%	%	%	%
Ventilation	%	%	%	%	%	%	%
Lighting	%	%	%	%	%	%	%
Dynamic building envelope	%	%	%	%	%	%	%
Electricity	%	%				%	%
Electric vehicle charging		%		%		%	%
Monitoring and control	%	%	%	%	%	%	%

Figure 6. Overview of technical domains, impact criteria and key functionalities of the SRI methodology

UNI / TS 11820

This technical specification (TS) provides guidance on how to measure and evaluate the circularity performance of an organization and use it to verify the effectiveness of circularity strategies through a set of circular economy indicators. The specific technique also provides the methodology for gathering the information needed to allow the measurement of circularity. The measurement system does not include a minimum circularity threshold value, but it allows to evaluate the level reached by the organization, compared to the maximum level reachable. The technical specification provides opportunities for improvement of the level of circularity over time.

The circularity measurement system is developed through a rating system on a basis of 100 and has a set of scalable indicators. This technical specification is applicable to organizations of all types and sizes, public or private out of two levels: micro (individual organization, local authority) and meso (group of organizations, industrial areas and districts, territories, regions, metropolitan areas and provinces). The macro level, such as countries, is excluded from the analysis.

3.3 EXPERIENCE FEEDBACK FROM PARTNERS PREVIOUS PROJECTS

In this section, the experience feedback from REHOUSE partners previous projects (European, Regional and local projects) is presented. The choice of these projects is justified by the experience acquired by the project partners which is related to the methodological part of performance evaluation and the KPIs selection. Thus, an overview description of these projects is presented below, the information related to the KPIs are presented in Annex III: Experience feedback from partners previous projects.

SEREINE

SEREINE is one of the 9 projects carried by the PROFEEL French program to emerge a collection of practical tools that contributes to the improvement of professional practices in the energy renovation market. Among PROFEEL program, the SEREINE project therefore aims to measure the actual performance of the renovated building at reception. The project proposes an in-situ method to quantify the share of consumption attributable the design, construction and renovation process and consequently characterize the performance of the building. The measurement protocol proposed aims to measure the partial performance indicator, which is the global insulation of the envelope, for the new or renovated house.

SmartEncity

SmartEnCity Horizon 2020 project (GA n°691883), aimed to develop a systemic approach to transform European cities into sustainable, smart and resource-efficient urban environments in Europe. The objective of this "lighthouse" project was to develop strategies that can be replicated throughout Europe in order to both reduce energy demand and maximize renewable energy supply. The project included activities on different fields as buildings retrofitting, new infrastructures integration, sustainable mobility development and the intelligent use of Information and Communication Technologies.

The SmartEnCity concept was defined, planned and implemented in three Lighthouse Cities: Vitoria-Gasteiz (Spain), Tartu (Estonia) and Sonderborg (Denmark), and the process was replicated in two Follower Cities: Lecce (Italy) and Asenovgrad (Bulgaria).

As monitoring and evaluation are indispensable parts of planning and implementing smart city interventions, it was developed an indicator system of Key Performance Indicators (KPIs) tailored to fit the project objectives, together with an evaluation plan, a data collection plan and a monitoring program, defining a baseline for the interventions as well as the expected performance, thus being able to assess the results after processing all the data. The evaluation methodology was made up of seven protocols named as Energy Assessment Protocol, ICT Protocol, LCA Protocol, Mobility Protocol, Social acceptance Protocol, Citizen Engagement Protocol and Economic Performance Protocol, covering each one the description of the objectives to be evaluated and the methods to be applied, as well as a set of KPIs which were used to quantify the results reached after the execution of the interventions. The KPIs the more related to REHOUSE are listed in Annex III: Experience feedback from partners previous projects.

REMOURBAN

REMOURBAN, (Regeneration Model for accelerating the smart urban transformation), is an

Horizon 2020 project (GA n°646511) that aimed at the development and validation in three lighthouse cities (Valladolid-Spain, Nottingham-UK and Tepebasi/Eskisehir-Turkey) of a sustainable urban regeneration model that leverages the convergence area of the energy, mobility and ICT sectors in order to accelerate the deployment of innovative technologies, organisational and economic solutions to significantly increase resource and energy efficiency, improve the sustainability of urban transport and drastically reduce greenhouse gas emissions in urban areas.

HOUSEFUL

HOUSEFUL is a Horizon 2020 project (GA n°776708) which proposes an innovative paradigm shift towards a circular economy for the housing sector by demonstrating the feasibility of an integrated systemic service composed of eleven circular solutions. HOUSEFUL introduce solutions to become more resource efficient throughout the lifecycle of a building, taking into account an integrated circular approach where energy, materials, waste and water aspects are considered. HOUSEFUL is demonstrated in 4 demo-sites in Austria and Spain, adapting the concept to different scenarios, including in social housing buildings. HOUSEFUL solutions are evaluated from an environmental (Life Cycle Assessment), economic (Life Cycle Cost) and social (Social Assessment) point of view.

SCIS

The Smart Cities Information System (SCIS) brings together project developers, cities, institutions, industry and experts from across Europe to exchange data, experience and know-how and to collaborate on the creation of smart cities and an energy-efficient urban environment. Launched with support from the European Commission, SCIS encompasses data collected from ongoing and future smart cities and energy efficiency projects co-funded by the European Union.

RINNO

RINNO is a Horizon 2020 project (GA n°892071) that aims to deliver a set of processes that when working together give a system, repository, marketplace, and enabling workflow process for managing deep renovation projects. The ultimate objective of RINNO is to dramatically accelerate the rate of deep renovation in the EU by reducing the time, effort and cost of deep renovation while improving energy performance and stakeholder satisfaction.

EENSULATE

EENSULATE is an EU HORIZON 2020 project (GA n°894617) that has the aim to validate an affordable (28% total costs reduction) and lightweight (35% weight reduction) solution for envelope insulation to bring existing curtain wall buildings to “nearly zero energy” standards while complying with the structural limits of the original building structure and national building codes. Two key commercial insulating products have been developed: i) highly insulating mono-component and environmentally friendly spray foam, EENSULATE foam, for the insulation of the opaque components of curtain walls; ii) lightweight and thin double pane vacuum glass, EESNULATE glass, for the insulation of the transparent component of curtain walls. Combining these products two modules have been provided during the project, EENSULATE Basic curtain wall and EESNULATE Premium modules.

P2ENDURE

P2Endure is an EU HORIZON 2020 project (GA n°723391) that has the aim to provide scalable, adaptable and ready-to-implement prefabricated Plug-and-Play (PnP) systems for deep renovation of building envelopes and technical systems. P2Endure presents a proof-of-performance of the optimized PnP renovation techniques by implementing 10 large-scale and live demonstration projects that represent the main deep renovation typologies and real market demand in 4 EU geo-clusters. The demonstration cases give evidence of the achieved 60% energy saving after deep renovation along with 15% cost saving and 50% time saving at renovation, and high indoor environmental quality.

MIRRORPANEL

The project main goal was to develop a new insulation system based on heat reflection. Based on this parallel stretched paper foils were placed perpendicular the heat flow direction. The surface of the paper foils was coated with nano particles which reflect the thermal radiation. The distance between the foils was 5 mm for prohibit the air circulation called convection. By means of this system the thermal conductivity was only 11% higher than that of the conductivity the still air. The project provides the possibility to build a test house in which the system was implemented and tested. The results were outstanding good, by reaching the 0.038 W/mK thermal conductivity and the U value of the wall was 0.08 W/m^{2}K. The heating demand of test building was less than 2 kWh.

The material for the foil was chosen paper to be as environment friendly as possible and only the surface coating was non-renewable materials. In parallel with the insulation development, the first version of Intelligent Window was worked out, in a completely different way and materials. The additional layer was a rolled plastic foil. The system decreased slightly the heat loss of the window, but the operation was very problematic especially the vapour and in cold weather the frost causes continuous problems. These problems will be eliminated in this project by using full double glass as shifting elements. For the intelligent window system there are not KPIs determined so far.

REEHUB

Main goal of the REEHUB (REGIONAL ENERGY EFFICIENCY HUB) INTERREG Project has been to increase energy efficiency of the public buildings within the regions' area of Albania, Puglia, Montenegro and Molise, thanks to a network of hubs, enabling the training of building managers on energy-efficiency measures. In addition, the project aims to guarantee suitable and effective communication to consumers and awareness-raising at all levels of society. Main output of the project is the creation of Energy Efficiency HUBs in each partner region (Tirana, Brindisi, Podgorica, Agnone) where all the stakeholders involved in energy efficiency actions can find tangible examples on best practices, technical instruments and guidelines for energy audit, and example of how citizens can contribute to a sustainable growth, in accordance with circular economy principles. So, the overall ambitious intent is to contribute to the shift from old buildings, responsible of consuming a lot of energy, to new ones with low or nearly zero energy consumption.

Table 5. KPIs used in the REEHUB project

Categories	KPIs (units)	Description
Energy saving	Number of energy audits done	The energy audit simplified gives the energy solution technology for improving energy saving in apartment and the result can be evaluated trough the EPC
Training	Number of participants in capacity building courses	Capacity building tailored to public administration

MADE GREEN IN ITALY

LIFE MAGIS (MAde Green in Italy Scheme) is a Project co-funded by the LIFE Programme of the

European Union to support the diffusion of the Made Green in Italy (MGI) scheme, promoted by the Italian Ministry of the Environment to valorise Italian products with the best environmental performances. The project aims at experimenting the MGI scheme, promoted by the Italian Ministry of the Environment with the Decree 56/2018 to assess and communicate the environmental value of Made in Italy products, developing and testing new Product Category Rules (PCR) for different sectors. With Decree No. 56/2018, which came into force on 13th June 2018, the regulation established the operating procedures of the scheme called "Made Green in Italy" aimed at promoting products with high environmental qualification through the use of the logo "Made Green in Italy". Products are defined as goods, services, intermediate or semi-finished products. The Made Green in Italy scheme is based on Product Environmental Footprint (PEF), a method to assess environmental impacts of goods and services developed and promoted by the European Commission to harmonize environmental evaluation and communication of products.

ELIH-MED

The ELIH-MED (Energy efficiency in low-income housing in the Mediterranean area and on the involvement of residents in energy retrofit in LIH) project has carried out a large-scale experimentation of cost-effective solutions and innovative public and private financing mechanisms backed with Structural Funds to foster energy efficiency investment in low-income households. The pilot projects were realized after a selection of the dwellings, through meetings with local actors related to energy efficiency and social housing, as well as with inhabitants, smart meters installation, launch of calls for tenders to select the providers and the refurbishment implementation.

BRICKS

The BRICKS (Building Refurbishment with Increased Competences, Knowledge and Skills) Project, within the BUILD UP Skills (Pillar I) EU initiative financed by EASME to increase the skills of workforce in the building sector on energy efficiency, developed tools and methodologies to strengthen the national training systems to increase the knowledge, skills and competences of workers in the field of buildings refurbishment.

PADOVA FIT

PadovaFIT Expanded brings together a strong consortium of eight partners coming from four EU Member States. Starting from the existing cooperation of the City of Padova (Italy) with the Romanian City of Timisoara (Romania), the project aims at expanding the business model to this city, benefitting from the work done in Italy and adapting it to the Romanian conditions, being ready to launch a one-stop-shop as well. Then, the Bulgarian Energy Agency of Plovdiv is supporting the cities of Vidin and Smolyan to take on the examples of Timisoara and Padova and prepare an action plan to develop two one-stop-shops in Bulgaria. To attain the project's objectives, several target groups will be involved: local and regional governments representing the 4 pilot areas, European institutions (EU Commission, European Investment Bank, Managing Authorities of the European Structural and Investment Funds), private sector (including ESCOs), local businesses, cooperatives financing institutions, insurance companies, building managers, homeowners and tenants. The role of public authorities is key for channelling private finance into energy efficiency investments. One- Stop- Shop solutions seem to have the highest potential to bring together all players involved in the renovation process, because of their holistic approach. The project has been set up in order to give a response to the current state of play which shows, in fact, a fragmented demand and fragmented supply. Energy efficiency improvements do make sense economically and are already technically viable, but the main reason why homeowners do not invest at this moment ultimately lies in market failure. Demand-Supply aggregation combined with attractive financial solutions is the main challenge the One-Stop-Shop is about to face.

PadovaFIT Expanded is aimed at:

- the identification of the enabling conditions and EU best practices that lead financially sustainable, integrated home renovation service schemes, based on public and/or private finance, supporting citizens to target ambitious energy savings,
- the reduction of the information gap existing in the private residential energy refurbishment sector, increasing the awareness and trust of homeowners and tenants towards existing products, services and players on the market,
- the improvement of standardized technical procedures in order to reduce costs and improve the quality of offer provided by trustful market operators,
- the improvement of financing conditions for energy renovation investment plans offered by the One Stop Shop,
- the development and implementation of a one-stop-shop providing home renovation integrated services to citizens in four pilot areas in three different countries,
- the identification of solutions to remove legal, policy framework, financial, technical, and organizational barriers limiting the implementation of effective and sustainable integrated home renovation services,
- the increase of the capacity of public and private energy market stakeholders with a specific focus on integrated home renovation services.

3.4 SOCIAL FRAMEWORKS

The social frameworks are described through 2 main frameworks grouping most of social indicators: Social Life Cycle Assessment and Social Urban framework.

3.4.1 SOCIAL LIFE CYCLE ASSESSMENT

Social Life Cycle Assessment (S-LCA) is a methodology to assess the social impacts of products and services across their life cycle (e.g., from extraction of raw material to the end-of-life phase, e.g., disposal). It offers a systematic assessment framework that combines quantitative as well as qualitative data. S-LCA provides information on social and socio-economic aspects for decision-making, in the prospect of improving the social performance of an organization and ultimately the well-being of stakeholders.

The S-LCA framework calls upon a stakeholder approach where the potential impacts on different stakeholder categories are considered. **This mirrors the fact that social sustainability is about identifying and managing impacts, both positive and negative, on people (stakeholders). Social impacts are classified by stakeholder categories to assist with the operationalization and to ensure the comprehensiveness of the framework.** The stakeholder categories are at the basis of an S-LCA assessment because they are the items on which the justification of inclusion or exclusion in the scope needs to be provided. **Linked to the stakeholder categories, are the impact subcategories** that comprise socially significant themes or attributes. These **subcategories are assessed using impact indicators**, of which inventory indicators link directly with the inventory of the product life cycle. Several indicators may be used to assess each of the subcategories. These indicators may vary depending on the context of the study [8].

Impact categories:

1. Human rights
2. Working condition
3. Health and safety
4. Cultural Heritage
5. Governance
6. Socio-economic repercussion

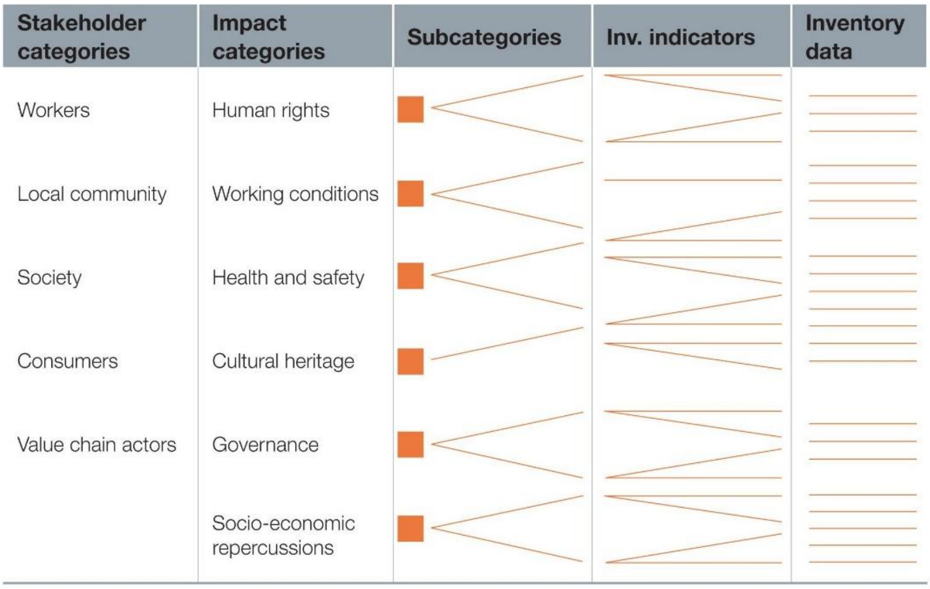

Figure 7. Relations between stakeholders' categories and inventory indicators

Due to complexity and number of criteria, for details about indicators refer to [8].

3.4.2 SOCIAL URBAN FRAMEWORK

The social urban frameworks contain a several social indicators applied mainly at urban scale. In some cases, these could be then derived at building scale also. One of the most important of them is energy poverty indicator.

Energy poverty is a complex phenomenon and as such it requires a well-structured definition, capable to consider all relevant issues, and a corresponding measure, based on available data.

There is not any official European definition of Energy poverty, and there is a large diversity of National agreed definitions, with countries adopting a definition based on an objective measure, others based on a mixed objective and subjective measure, or referred to social aids. Examples of agreed definitions based on objective measures define a household as energy poor if:

1. Purchasing a minimum set of good and services and having access to energy services implies a resource distraction (in income or expenditure terms) higher that a "normal value" (IT);

2. The amount they would need to spend to keep their home at "an adequate standard of warmth" is above the national median level and if they spent that amount, their leftover income would be below the official poverty line (UK).

In order to help Member States to fight energy poverty, through the improvement of measuring, monitoring and sharing of knowledge and best practice, in 2018 the European Commission launched the Energy Poverty Observatory (EPOV). EPOV has provided an enormous contribution to the preparation of comparative and robust statistics on energy poverty that are publicly accessible. The results achieved in the first year of its existence are consistent with the rationale behind its creation, showing that energy poverty is more widespread than expected across the EU. 28 primary and secondary indicators are defined by EPOV. Primary indicators are four, two of which based on self-reported experiences of limited access to energy services, and the other two calculated using household income and/or energy expenditure data. Secondary indicators are instead relevant in the context of energy poverty, but not directly indicators of energy poverty itself (e.g. energy prices and housing-related data). Both primary and secondary indicators can be computed by using Eurostat data. This shows that data on EU countries are available on different dimensions of energy poverty, the relevance of which depends on the definition of energy poverty adopted.

To measure energy poverty, EPOV recommends using multiple indicators in combination. Primary indicators were defined as follows:

1. High share of energy expenditure in income (2M): part of population with share of energy expenditure in income more than twice the national median (source: EPOV, 2010 HBS).
2. Hidden energy poverty (HEP): part of population whose absolute energy expenditure is below half the national median (source: EPOV, 2010 HBS).
3. Inability to keep home adequately warm: based on self-reported thermal discomfort (source: Eurostat, 2016 SILC).
4. Arrears on utility bills: based on households' self-reported inability to pay utility bills on time in the last 12 months (source: Eurostat, 2016 SILC).

Member States compute energy poverty measures basing on national surveys which have different periodicity from one country to another. The work of EPOV is already devoted to procuring the full micro datasets for the EU Statistics on Income and Living Conditions and the Household Budget Survey, but some delays have been experienced (Thomson and Bouzarovski, 2018). EPOV provided a key contribution in rationalising existing information and providing it on a comparable basis for all MS, but now the problem seems to be the lack of a harmonised measure.

Currently the Energy Poverty Advisory Hub has stressed again that energy poverty is a multi-dimensional concept that is not easily captured by a single indicator. A complete overview of all the indicators available with important information about the sources, technical details and additional insights is presented in the EPAH report "Energy Poverty National Indicators: Insights for a more effective measuring. After tracking down the data sources and original datasets, the indicators were updated with new data for recent years when available. Moreover, the designation and unit of several indicators were revised to match the original source, indicators' disaggregation was standardized, and some indicators were grouped, aiming to simplify the overall organisation and improve clarity and readability. Overall, the past 28 indicators selected by EPOV were reorganized and converted into a total of 21 indicators without removing any of the original indicators

Furthermore, EPAH developed a dashboard on these indicators: Energy Poverty Advisory Hub [9]. Under these circumstances, an indicator at building level is not applicable. The Covenant of Mayors [9] is carrying out a work to provide indicators useful for municipalities. They created **a series of 56 local energy poverty indicators** in collaboration with EPAH.

The local energy poverty indicators are also connected to Climate and Participation and awareness raising areas, linked i.d. to the resilience and engagement/social cohesion issues. Several EU projects are working on these topics, but results are not public or not yet available.

Hereafter the description of some of the social urban frameworks which have been identified.

ORCA

ORCA is the Italian Apulia Regional Observatory on Social Housing. It is an Observatory for analysis and assessment of the housing condition capable of providing cognitive support to the policies of the Region and local authorities. It is a social housing Platform that collect all tools and protocol for regional social housing and vulnerable areas.

POPolare

It is City initiative for social housing digitalization, funded by regional funds, for improving digitalization in social housing through the installation of Smart wall. The MOSAIC SMART wall provides digital services to citizens such as climate data, mobility information, Wi-Fi. The KPI could be Number of Wi-Fi access and information request on CO_2 and Transport and Digital services.

ITALIA IN CLASSE A

ITALIA IN CLASSE A is a national campaign promoted by the Ministry of Economic Development and implemented by the ENEA National Agency for Energy Efficiency, aimed at promoting a more efficient use of energy and providing the tools and opportunities to implement them to accelerate the energy transition process in our country. The ITALIA IN CLASSE A campaign includes a series of training and information activities aimed at the Public Administration, large companies and SMEs, to banking institutions, families and students which have been carried out from 2016 to 2020 throughout the national territory.

In order to reach a variety of target audiences, different actions and tools (Roadshow, Radio-TV Campaign, energy efficiency month, apps) have been used throughout the campaign.

The program aims to reach goals related to decarbonizing the EU's energy system to reach 2030 climate objectives and to become carbon neutral by 2050.

Due to the nature of the framework, the performance indicators are mainly related to the number of retrofitting initiatives linked to information and training actions through behavioural change actions.

A method has been developed to measure impacts, reported to EC and approved. Furthermore, an attitudinal survey, carried out in 2019, evaluated the effects of information campaigns: in particular, a representative sample of the Italian adult population was reached, for a total of 3,036 respondents.

DECIWATT

Metropolitan City of Milan and ENEA have created the single DeciWatt service dedicated to supporting citizens, condominium administrators, freelancers and technicians of local authorities in the process of renovation and energy efficiency of buildings through easy-to-use tools.

The objectives of the supporting services to citizens and building owner in renovation energy process, are:

- Promote the redevelopment of public and private buildings in order to achieve a decarbonised building stock by 2050, as envisaged by the European Union.
- Aggregate the different redevelopment projects of a building, guaranteeing a greater level of trust of the lenders.

- Contribute to raising the level of knowledge on energy issues, increase awareness of the importance of building renovations, among all stakeholders in the supply chain.

Due to the nature of the framework, the main indicator of the performances is related to the number of on-line requests received by the program, through their website or other alternative channels. Information about the DeciWatt program are available at the following website [10].

4 SUMMARY OF KPIS AND CLASSIFICATION

The detailed inventory of the regional, national and international MEL, and social frameworks and projects given in the section 3 has resulted into a synthesis of the KPIs presented in this section. To be in adequacy with the objectives of the REHOUSE project and the European LEVEL(s) framework the summary of KPIs given in this section is classified by 3 criteria:

1. Scale. The KPIs are given at the scale of renovation packages, buildings and at the scale of territory/city.
2. Macro-objectives (MO) of the LEVEL(s) framework described into the section 2.2.
3. Category. The KPIs are classified by domain related to construction projects.

The links between these classifications are illustrated on the Figure 8. The building' KPIs are mainly based on the KPIs from the LEVEL(s) framework augmented with the results of MEL inventory defined by REHOUSE project partners which together with Renovation Packages' KPIs create a basis for the definition of the REHOUSE project KPIs in the task 3.2. The results of the MEL inventory by project partners allow also to identify some additional KPIs which are not considered by the LEVEL framework.

The city/territory' KPIs are less of interest for the REHOUSE project as the biggest part of them are applicable only at territory scale. Nevertheless, some of them could be adapted to a building scale and so be further selected as relevant to be used in the REHOUSE project.

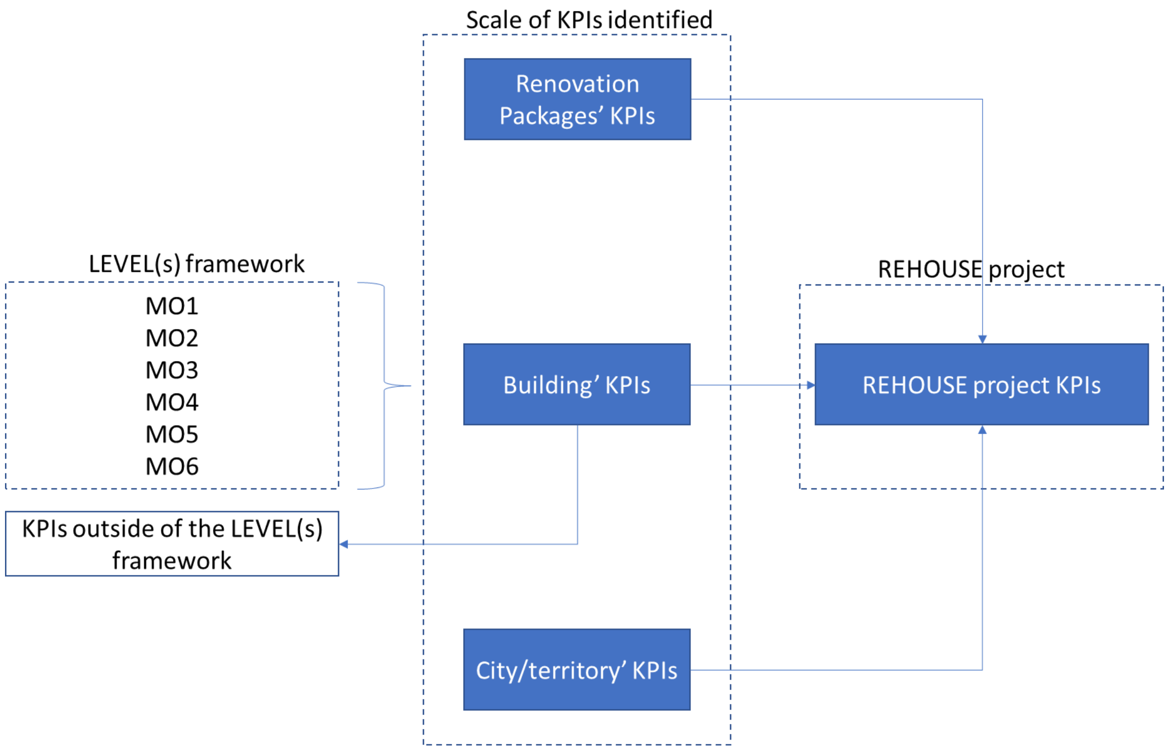

Figure 8. Synthesis of classifications of KPIs identified in the section 4

For the purposes of KPIs definition of the REHOUSE project in the Task 3.2 all the KPIs have been classified by the next categories:

- Building envelope. Here are included indicators related to thermal parameters of building walls and roof.
- Resource use. This category integrates indicators related to building energy and water consumption, as well as the amount of waste generated.
- Comfort conditions. It integrates indicators related to thermal, acoustic and visual comfort as well as the IAQ.
- Economics. It integrates indicators related to the cost dimension of construction process.
- Social/user’s behaviour. This category includes indicators related to the evaluation of impact of building use on life of users and changes in users’ behaviour inside or outside the building/dwelling they live.
- Environment and built environment. It integrates indicators related to greenhouse gases emissions of buildings in operational phase, as well as those associated to the outdoor environment of building or construction site.
- Resources re-use. This category includes indicators related to recycling and reuse of materials, wastes and other goods.

These categories cover all different domains of construction projects.

4.1 BUILDINGS SCALE KPIS

The next KPIs are better adapted to the buildings scale.

4.1.1 LEVEL MACRO-OBJECTIVE 1

As it is mentioned into the user manual 1 of the LEVEL framework [11] the Macro-Objective 1 goal is to minimize the total GHG emissions along a building's lifecycle, with a focus on building operational energy use emissions and embodied emissions. This MO integrates the KPIs and actions at building level with a focus on the objectives of:

- Near zero energy consumption during the use phase, supplemented by the contribution of cost effective and low/zero emission energy technologies and infrastructure.
- Embodied GHG emissions along the building's whole life cycle, including those associated with product manufacturing, maintenance, repair, adaptation, renovation and end of life.

The core indicators considered by this MO are the use stage energy performance (kWh/m^2/yr) and Life cycle Global Warming Potential (kg CO_2 eq./m^2/yr). The Life Cycle Global Warming Potential indicator (sometimes referred as a carbon footprint) is a complex indicator which measures the GHG emissions associated with the building at different stages along the life cycle. It therefore measures the building's contribution to emissions that contribute towards the earth's global warming, and the associated effects on climate change.

The KPIs from the section 3 related to the MO1 are given in the Table 6.

Table 6. The KPIs related to the MO1 of the LEVEL framework

Category	KPI Indicator (units)	Description	Associated data points/technical domains considered for assessment	Assessment method/calculation formula if available
Resource use	Primary energy consumption CEP (kWhep/m²/yr)	This indicator from the French Environmental regulation RE2020 is the indicator of conventional energy consumption of 5 principal energy uses in one building. This KPI doesn't't take into account locally produced and self-consumed energy.	Energy consumption: heating, cooling, lightings, ventilation, auxiliary	Cep = cep(heating) + cep(DHW) + cep(cooling) + cep(lightings) + cep(ventilation) + cep(auxiliary)
Resource use	Non-renewable primary energy consumption CEP,nr (kWhep/m²/yr)	This indicator is the same as the CEP at the difference that it takes into account only non-renewable energy	Non-renewable energy consumption: heating, cooling, lightings, ventilation, auxiliary	Cep,nr = cep,nr(heating) + cep,nr(DHW) + cep,nr(cooling) + cep,nr(lightings) + cep,nr(ventilation) + cep,nr(auxiliary)
Resource use	SRI score (%)	This score is the indicator of smart readiness of the buildings developed	The SRI methodology builds on the assessment of the smart ready	An aggregated SRI score can be derived as follows: - Assessment of

Category	KPI Indicator (units)	Description	Associated data points/technical domains considered for assessment	Assessment method/calculation formula if available
		and promoted by the EC. This score expresses how close the building is to the maximal smart readiness. The higher the percentage is the smarter the building. There are 7 impact criteria considered by this score: 1. Energy savings on site; 2. Flexibility for the grid and storage; 3. Comfort; 4. Convenience; 5. Well-being and health; 6. Maintenance and fault prediction; 7. Information to occupants.	services present in a building. Services are enabled by (a combination of) smart ready technologies and structured within nine domains: 1. Heating, 2. Cooling, 3. Domestic hot water, 4. Controlled ventilation, 5. Lighting, 6. Dynamic building envelope, 7. Electricity, 8. Electric vehicle charging, 9. Monitoring and control.	individual smart ready services. For each service, this leads to an impact score being ascribed for each of the impact criteria considered in the methodology. - Assessment of an aggregated impact score (domain impact score) which is calculated for each of the domains considered in the methodology. - Assessment of a total impact score which is calculated as a weighted sum of the domain impact scores. SRI score in % = Smart Readiness building/ Maximum smart readiness
Resource use	Degree of thermal energetic self-supply: DET (%) Degree of electrical energetic self-supply: DEE (%)	These indicators are from the SCIS European project (Smart Cities Information System) KPI guide. The degree of energetic self-supply is defined as ratio of locally produced energy and the local consumption over a period of time (year). The indicators are separately determined for thermal energy (heat or cold) and electricity. Furthermore, the quantity of locally produced energy can be interpreted as by renewable energy sources (RES) produced energy or by combined heat and power (CHP) plants produced energy	• Locally produced thermal energy [kWh/month ; kWh/year] : LPET • Locally produced electrical energy [kWh/month ; kWh/year] : LPEE • Thermal energy consumption (monitored) [kWh/(month) ; kWh/(year)] : TEC • Electrical energy consumption (monitored) [kWh/(month) ; kWh/(year)] : EEC	DET = LPET / TEC * 100 DEE = LPEE / EEC * 100

Category	KPI Indicator (units)	Description	Associated data points/technical domains considered for assessment	Assessment method/calculation formula if available
Resource use	Energy savings (%) Normalized energy savings (kWh/m2year)	These indicators are identified as key performance indicators for holistic evaluation of building retrofits in Ho and al. Literature review [12]	Energy consumption before and after the retrofit	Amount of energy saved as a result of the retrofit project
Resource use	• Use of non-renewable primary energy resources used as raw material (MJ) • Use of non-renewable primary energy excluding energy resources used as raw material (MJ) • Use of renewable primary energy resources used as raw (MJ) • Use of renewable primary energy excluding energy resources used as raw material (MJ)	These indicators Are presented in the SmartEnCity European project	Life Cycle Impact Assessment Methods	Cumulative energy demand methodology. Method to calculate Cumulative Energy Demand (CED), based on the method published by Ecoinvent version 2.0 and expanded by PRé Consultants for raw materials available in the SimaPro 7 database
Environment	Ozone Depletion Potential (kg CFC-11 eq)	This indicator represents the impact on the ozone layer	LCIA	LCIA method
Environment	Radiative forcing as Global Warming Potential : (kg CO_2 eq)	Indicator from the SmartEnCity set of indicators. This indicator attempts to integrate the overall climate impacts of a specific action. It relates the impact of emissions of a gas to that of emission of an equivalent mass of	LCA study The duration of the perturbation is included by integrating radiative forcing over a time horizon. The time horizon thus includes the cumulative climate	LCA tool Baseline model of 100 years of the IPCC

Category	KPI Indicator (units)	Description	Associated data points/technical domains considered for assessment	Assessment method/calculation formula if available
		CO_2.	change and the decay of the perturbation.	
Resource use	Non-renewable primary energy (%)	Improve the energy performance of the building by reducing non-renewable primary energy during the operational phase of the building.	Building energy consumption (kWh), Building energy consumption from renewable energy (kWh)	Percentage reduction of the non-renewable energy performance index (percentage ratio between the global non-renewable primary energy index of the EPgl,nren building and the corresponding value of the reference building EPgl,nren,ref,standard (2019/21) used for the calculation of the energy class) (B.1.2 from ITACA).
Environment and built environment	Total primary energy (%)	Improve the energy performance of the building by reducing the total primary energy during the operational phase of the building.	Building energy consumption (kWh)	Percentage reduction of the total energy performance index (percentage ratio between the total overall energy performance index of the building to be assessed EPgl,tot and the corresponding limit value of the reference building EPgl,tot,lim for the corresponding years of validity)(B.1.3 from ITACA).
Resource use	Renewable energy for thermal uses (%)	Promote the production of thermal energy from renewable sources.	Thermal energy produced from renewable sources (kWh)	Share of thermal energy from renewable sources (QR) (B3.2 from ITACA).
Resource use	Energy produced on site for electrical uses (%)	Encourage the use of electricity produced from renewable sources.	Electricity produced by RES plants on, inside or in the immediate vicinity of building (kWh)	Percentage ratio between the electricity produced by RES plants installed on or inside or in the immediate vicinity of the project building and the electricity produced by reference RES plants (B.3.3 from ITACA).
Resource use	Heat energy useful for heating (%)	Reduce the need for useful energy for heating (EPH,nd) during the operational phase of the building.	Heating energy consumption (kWh), Heating energy consumption of a	Percentage ratio between the useful energy requirements for heating of one building and that of a reference

Category	KPI Indicator (units)	Description	Associated data points/technical domains considered for assessment	Assessment method/calculation formula if available
			reference building (kWh)	building (minimum useful energy requirements for the corresponding years of validity) (B.6.1 from ITACA).
Resource use	Thermal energy useful for cooling (%)	Reduce the need for useful energy for cooling (EPC,nd) during the operational phase of the building.	Cooling energy consumption (kWh), Cooling energy consumption of a reference building (kWh)	Percentage ratio between the useful energy requirements for cooling of one building and that of a reference building (minimum useful energy requirements for the corresponding years of validity) (B.6.2 from ITACA).
Building envelope	Global mean heat transfer coefficient (%)	Reduce heat exchange by transmission during the winter period.	Heat flux (W/m^2) through walls and roof, surface temperatures on indoor and outdoor surfaces of walls and roof (°C), air temperature inside and outside the building (°C)	Percentage ratio between the global average heat transfer coefficient H'T of one building and that corresponding to the legal limits (B.6.3 from ITACA).
Building envelope	Average solar transmittance of window/screen packet gf	This indicator characterizes the capacity of window/screen packet to reduce solar intake in the summer by controlling solar radiation going through.	Solar energy outdoor near window (W/m^2), solar energy indoor near window (W/m^2)	Average effective solar transmittance of the window/screen packet (gf') (B.6.4 from ITACA).
Environment and built environment	Projected operational emissions (%)	Reduce the amount of CO_2 equivalent emissions from non-renewable primary energy used for the annual operation of the building.	Amount of annual CO_2 equivalent emissions associated to the operation of building (kg CO_2 eq)	Percentage ratio between the amount of annual CO_2 equivalent emissions produced for the operation of one building and the amount of CO_2 equivalent emissions corresponding to a reference building (minimum requirements DM 26 June 2015) (C.1.2 from ITACA).

4.1.2 LEVEL MACRO-OBJECTIVE 2

The Macro-Objective 2 goal is to optimize the building design, engineering and form in order to support lean and circular flows, extend long-term material utility and reduce significant environmental impacts. This MO integrates the KPIs and actions at building level with a focus on material efficiency and circular utility. This encompass actions along the life cycle relating to:

- building design,
- structural engineering and construction management,
- construction product manufacturing,
- replacement cycles and flexibility to adapt to change, and
- the potential for deconstruction.

The overall scope is to optimize material use, reduce waste and introduce circularity into designs and material choices.

The core KPIs considered by this MO are the next ones:

- Bill of quantities, materials and lifespans. These KPIs are expressed in unit quantities, mass and years.
- Construction & demolition waste and materials. These KPIs are expressed in kg of waste and materials per m^2 total useful floor area.
- Design for adaptability and renovation. This KPI is given in the format of the Adaptability score.
- Design for deconstruction, reuse and recycling. This KPI is given in the format of the Deconstruction score.

The KPIs from the section 3 related to the MO2 are given in Table 7.

Table 7. The KPIs related to the MO2 of the LEVEL framework

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Resource use	Total Waste (tonnes / m^2)	The tonnes of waste removed from the asset during the reporting year per square metre of the asset (GIA: Gross Internal Area: the whole enclosed area of a building within the external walls, taking each floor into account and excluding the thickness of the external walls)	Data from Building owner, construction/ demolition company	The tonnes of waste removed from the asset during the reporting year per square metre of the asset
Resource re-use	Proportion of Waste Recycled (%)	Percentage of total waste produced by the asset which is recycled	Data from Building owner, construction/demolition company	Percentage of waste that is recycled in relation to total waste
Resource use	Proportion of Waste to Landfill (%)	Percentage of total waste produced by the asset which is sent to landfill	Data from Building owner, construction/ demolition company	Percentage of waste to Landfill in relation to total Waste

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Resource use	Hazardous wastes disposed (kg)	Amount of hazardous and non-hazardous wastes disposed during the life cycle of the district intervention according to the current European legislation. Non-hazardous wastes disposed Directive 2008/98/EC and Annex III to Directive 2008/98/EC	Data from Building owner, construction/ demolition company	Life Cycle Inventory account
Resource use	Non-hazardous wastes disposed (kg)		Data from Building owner, construction/ demolition company	Life Cycle Inventory account
Resources re-use	Reuse of existing facilities (%)	Encourage the reuse of most existing buildings, discourage demolition and demolition of buildings in the presence of recoverable structures.	Data from Building owner, construction/ demolition company	Percentage of envelope surfaces and floors of existing construction that is reused in the project (B.4.1 from ITACA).
Resources re-use	Recycled/recovered materials (%)	Encourage the use of recycled materials and / or recovery to reduce the consumption of new resources.	Data from Building owner, construction/ demolition company	Percentage by volume of recycled and/or recovered materials used in the intervention (B.4.6 from ITACA).
Resources re-use	Materials from renewable sources (%)	Reduce the consumption of non-renewable raw materials.	Data from Building owner, construction/ demolition company	Percentage by volume of materials from renewable sources used in the intervention (B.4.7 from ITACA).
Resource use	Local materials (%)	Promote the procurement of local materials.	Data from Building owner, construction /demolition company	Percentual weight of local materials compared to those used in the construction of the building (B.4.8 from ITACA).
Resources re-use	Recyclable or removable materials (N/A)	Encourage design that allows selective dismantling of components so that they can be reused or recycled.	Data from Building owner, construction/ demolition company	Number of application areas of solutions/strategies used to facilitate disassembly, reuse or recycling of components (B.4.10 from ITACA).
Resource use	Certified materials (N/A)	Encourage the use of construction products bearing Type I or Type III environmental labels/declarations.	Data from Building owner, construction/ demolition company	Number of products bearing Type I or Type III environmental labels/declarations (B.4.11 from ITACA).
Resource use	Mineral and metal - Abiotic resource depletion (ADP ultimate reserves) kg Sb eq	These indicators refer to the removal of abiotic resources for mineral, metal and fossil resources	Data to be extracted from LCA tools	Consistent Life Cycle Inventory activity; commercial tool for LCA calculation process

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Resource use	Fossil resources - Abiotic resource depletion – fossil fuels (ADP-fossil) (MJ)			
Environment and built environment	Solid waste generated in the operational phase (%)	Promote the separate collection of solid waste	Data from Building owner, facility manager company	Ratio between the number of types of waste for which there is an area used for separate collection within 50 meters from the entrance of one building compared to the types of reference waste (C.3.2 from ITACA).
Resources re-use	Land reuse (%)	Encourage the reuse of excavated earth in situ.	Data from construction/ demolition company	Percentage by volume of excavated earth reused in situ (C.3.3 from ITACA).

4.1.3 LEVEL MACRO-OBJECTIVE 3

The Macro-Objective 3 goal is to make efficient use of water resources, particularly in areas of identified long-term or projected water stress. This MO integrates KPIs and actions at building level, in particular for buildings located in areas of continuous or seasonal water stress. This could combine efficiency measures to minimize water use, as well as supply-side measures such as grey water reuse and rainwater harvesting, designed to make use of alternative sources.

The core KPI considered by this MO is the use stage water consumption (m^3/yr of water per occupant).

The KPIs from the section 3 related to the MO3 are given in the Table 8.

Table 8. KPIs related to the MO3 of the LEVEL framework

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Resource use	Potable water for irrigation (%)	Reduce the consumption of drinking water for irrigation through the use of recovery strategies or optimization of water use.	Water consumption for irrigation (m^3)	Volume of drinking water saved compared to the calculated basic requirement (B.5.1 from ITACA).

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Resource use	Potable water for indoor use (%)	Reduce the consumption of drinking water for indoor use through the use of recovery strategies or optimization of water use. This indicator is considered in ITACA protocol, as well as by HQE Bâtiment Durable label and LEED certification	Water consumption for indoor use (m^3)	Volume of drinking water saved for indoor use compared to the calculated basic requirement (B.5.2 from ITACA).
Environment and built environment	Grey water sent to sewerage (%)	Minimize the amount of effluent discharged into the sewer.	Grey water consumption sent to sewerage (m^3), indoor water needs (m^3)	Ratio between the volume of liquid waste not generated and the reference quantity calculated on the basis of indoor water needs (C.4.1 from ITACA).
Resource use	Rainwater management	This indicator is introduced by the Global Reporting Initiative (GRI). It represents rainwater collected directly and stored by the organization/ building.	Rainwater level (height in m or volume in m^3) in storage tanks or rainwater consumption for irrigation and indoor uses (m^3)	Volume of rainwater consumed by building or its environment or stored inside the building
	Reduction and recovery of rainwater introduced into the sewer	Minimize the amount of rainwater send to the sewer	Rainwater consumption on site (m^3), rainwater send to the sewer (m^3)	Ratio between rainwater consumed directly on site for different needs (irrigation or indoor use) and rainwater sent to the sewer

Several international labels and certifications promote and evaluate technical measures to reduce water consumption from city water grid. The KPIs entering in this category are the next ones:

- Rainwater management (recover rainwater and use it in indoor or outdoor of the building to reduce water consumption from city water grid). This KPI is taken into consideration into next labels and certifications: NF Habitat HQE Rénovation label, HQE Bâtiment Durable label, LEED, Living Building Challenge, Pétale 2 : L'EAU
- Wastewater management and treatment (manage entire water use cycle from chemical-free filtration to recovery of grey and black water). This KPI is considered in HQE Bâtiment Durable label, Living Building Challenge, Pétale 2 : L'EAU, E+C- label, WELL Building standard
- Leak detection and prevention to maintain a good level of comfort and avoid additional water consumption. NF Habitat HQE Rénovation label and BREEAM include this KPI in the list of points to be evaluated.
- Water quality KPI evaluates the capacity of building to reduce the risk of water contamination and ensure a quality water supply for the building's occupants. This KPI is considered by Osmoz label and WELL Building standard.
- Presence of water-saving equipment is taken in consideration by BREEAM certification.

4.1.4 LEVEL MACRO-OBJECTIVE 4

The Macro-Objective 4 aims to create buildings that are comfortable, attractive and productive to live and work in, and which protect human health. The scope of this MO is to address critical aspects of indoor environmental quality that influence occupier health, comfort and productivity, the first four of which being:

- the quality of the indoor air for specific parameters and pollutants,
- the degree of thermal comfort during an average year,
- the quality of artificial and natural light and associated visual comfort, and
- the capacity of the building fabric to insulate occupiers from internal and external sources of noise.

The core KPIs considered by this MO4 are the next ones:

- Indoor air quality. Several indicators are included as the parameters for ventilation, air exchange, CO_2 rate and relative humidity. Target list of pollutants considered: TVOC, formaldehyde, CMR VOC, LCI ratio, mould, benzene, particulates, radon;
- Time outside of thermal comfort range which is the percentage of the time (%) out of range during the heating and cooling seasons;
- Lighting and visual comfort accordingly to Level 1 checklist ;
- Acoustics and protection against noise accordingly to Level 1 checklist.

The KPIs from the section 3 related to the MO4 are given in the Table 9. All these are related to the category Comfort conditions.

Table 9. KPIs related to the MO4 of the LEVEL framework

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Comfort conditions	Summer Degree-hours of discomfort DH (°C*h)	This indicator is introduced by the French Environmental regulation RE 2020 and presents an important evolution on the summer comfort subject. It represents the discomfort level perceived by the occupants.	Ambient temperature in living-room and rooms of dwellings	This indicator is similar to a counter that accumulates, during the summer period, every uncomfortable degree of every hour during the day and night.
Comfort conditions	Users' perspective	It is a specific category of KPIs for holistic evaluation of building retrofits. Among others the main KPIs are: 1. U3 Target indoor air temperature (°C) 2. U7 Δ Indoor CO_2 levels/other harmful substances (ppm)	• Indoor air temperature (°C) • Indoor CO_2 levels/other harmful substances (ppm) • IAQ class • Work plane illuminance (lux) • Equivalent continuous	For each KPI a precise calculator methodology is specified in [12]

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
		3. U8 Target IAQ class 4. U11 Target work plane illuminance (lux) 5. U12 Target equivalent continuous weighted sound pressure level (dBA)	weighted sound pressure level (dBA)	
Comfort conditions	Comfort conditions of the occupants: thermal comfort, acoustic comfort, visual comfort and indoor air quality	Regulation for the Energy Efficiency of Buildings (KENAK)	Air quality (based on EN 15251:2007) Lighting and visual comfort (based on EN 12464.1-2011) DHW (based on EN 15316.3.1:2008)	These indicators are a set of yes/no options
Comfort conditions	SRI score (%)	Described in the MO1	Described in the MO1	Described in the MO1
Comfort conditions	Relevant KPIs (under the category Health and wellbeing): 1. Hea 14 Thermal comfort 2. Hea 15 Smoking policy 3. Hea 16 Indoor air quality management 4. Hea 17 Acoustic conditions 5. Hea 18 Legionella risk management	BREEAM (Building Research Establishment Environmental Assessment Method) is a certification that must be carried out by trained assessors based on a scoring system based on performance benchmarks	Ambient temperature (°C), Measurement of parameters of IAQ (ppm, ppb), Acoustic isolation of facades, Acoustic isolation of inside walls between dwellings or offices, acoustic isolation between floors, measurements of presence of legionella in potable hot water circuits	1. Occupant thermal satisfaction surveys ANSI/ASHRAE Standard 55-2017 2. yes/no 3. Local and international standards, testing protocols and labelling initiatives for low emission products. 4. Measuring or calculating the levels required to demonstrate compliance with this assessment issue. 5. Legionella prevention and control measures
Comfort conditions	Thermal Comfort (score)	The WELL Thermal Comfort concept aims to promote human productivity and provide a maximum level of thermal comfort among all building users through improved HVAC system design and control and by meeting individual thermal preferences	Operative temperature (°C), dry-bulb temperature (°C), relative humidity (%)	Baseline satisfaction by thermal comfort conditions through a survey for the largest number of building occupants. It could be also supported by thermal comfort monitoring.

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Comfort conditions	Thermal comfort PMV (Provisional Mean Vote) and PPD (Provisional Percentage of Discomfort)	The GPP MEC for buildings is an implementing tool of Italy's "National Action Plan for environmental sustainability of Public procurement". The MEC concerns all types of interventions on public buildings, regardless of the entity of the works.	Sensors and meters are used to collect values	UNI EN ISO 7730
Comfort conditions	Thermal comfort design and verification	Technical specification UNI/TS 11820 defines a set of indicators suitable for assessing, through a rating system, the level of circularity of an organisation or group of organisations.	Sensors and meters are used to collect values	UNI/TS 11820
Comfort conditions	Internal air temperature (°C)	It is directly involved in the determination of internal comfort condition, but it also allows to investigate (with another parameter as the heat quantity for set point achievement) how much energy is necessary to reach a particular desired condition known as set point.	Sensors and meters are used to collect values	Use parameters (before and after an Energy Conservation Measure (ECM) considering the same set point condition) allows to know how much heating energy has been saved thanks to the ECM's interventions (from SmartEnCity project)
Comfort conditions	Heat quantity for set point achievement (kWh)	It allows to collect information about the quantity of energy that is needed to reach a particular temperature condition known as set point.	Meters are used to collect values	Using data before and after an ECM (considering the same set point condition) allows to know how much heating energy has been saved thanks to the ECM's interventions (from SmartEnCity project)
Comfort conditions	Thermal comfort	This indicator represents the level of thermal comfort measured as the number of hours that the indoor temperature and relative humidity conditions are within range of values defined. The range of comfort values varies with the seasons (as it depends on the metabolic rate and clothing of the building users) and the climatology of each city	Meters are used to collect values	Using data before and after an ECM (considering the same ambient conditions) allows to know the impact of the ECM on the individual comfort conditions (from SmartEnCity project)

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
		(average monthly temperatures (max & min) and average monthly relative humidity).		
Comfort conditions	Internal relative humidity (%)	Percentage ratio between the quantities of vapour included in an air mass and the maximum quantity of vapour that the same air mass could include under the same conditions of temperature and pressure.	Meters are used to collect values	Saturation of the atmospheric & vapour value, primary for comfort conditions and ambient healthfulness, should be comprehended between 55% - 65% (from SmartEnCity project)
Comfort conditions	Internal air speed and distribution (m/s)	Through this parameter it's possible to know the movement of the air inside the internal ambient. The movement of the air contributes to the healthfulness of the internal air quality level but, this same movement, in function of its speed, could also produce changes in individual comfort conditions due to the augment of the convection heat dissipation or to improper air flows.	Meters are used to collect values	Using data before and after an ECM (considering the same ambient conditions) allows to know the impact of the ECM on the individual comfort conditions (from SmartEnCity project)
Comfort conditions	Ventilation and air quality (N/A)	Ensure ventilation that allows you to maintain a high degree of air healthiness.	Ventilation rate (m^3/h)	Design strategies to ensure the necessary air changes in the premises (D.2.5 from ITACA).
Environment and built environment;	Radon (N/A)	Minimize exposure to radon, controlling its migration from soils to indoor environments.	Indoor radon concentration (Bq/m^3)	Presence/absence of design strategies for Radon migration control (D.2.6 from ITACA).
Comfort conditions	Summer thermal comfort in air-conditioned rooms (N/A)	Maintain a satisfactory level of thermal comfort in mechanically cooled environments.	Ambient temperature (°C)	Thermal comfort category (D.3.1 from ITACA)
Comfort conditions	Summer Comfort (N/A)	The method has to be executed by certified diagnosticians. The KPI is calculated by specific software for DPE evaluation.	The parameters taken into account to assess the summer comfort: - Housing inertia - Through-housing - Presence of air blowers - Insulated roof - Solar protections on	The calculation formula is not available. 3 levels are possible: insufficient, medium and good

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
			the windows	
Comfort conditions	Operating temperature in summer (°C)	Maintain a satisfactory level of thermal comfort during the summer.	Operating temperature (°C)	Average deviation between the operating temperature and the ideal room temperature in summer (ΔTm) (D.3.2 from ITACA).
Comfort conditions	Winter thermal comfort in air-conditioned rooms (N/A)	Maintain a satisfactory level of thermal comfort in mechanically heated rooms.	Ambient temperature (°C)	Category of thermal comfort (D.3.3 from ITACA).
Comfort conditions	Natural lighting (%)	Ensure adequate levels of natural lighting in all occupied primary spaces.	Luminance (lux) measured in absence of any artificial lighting	Average daylight factor of the rooms of the building (Dm) (D.4.1 from ITACA).
Comfort conditions	Acoustic quality of the building (N/A)	Protection from external and internal noise of the building.	Indoor and outdoor noise measurement (dB)	Global acoustic class of the building (D.5.6 from ITACA).

Additional indicators not considered currently by the MO4 of the LEVEL framework, but related with it, concerns the indoor exposition of individuals to a high level of electric and magnetic fields at industrial frequency (50 Hz). This indicator, described into the D.6.1 section of Italian ITACA protocol, takes into account rooms belonging to housing units with significant sources of industrial frequency magnetic field such as: transformer substations, electrical switchboards at the level of dwelling units, underground medium- and high-voltage lines and evaluates strategies adopted for the reduction of exposure to these magnetic fields.

4.1.5 LEVEL MACRO-OBJECTIVE 5

The Macro-objective 5 aims to protect futureproof building performance against projected future changes in the climate, in order to protect occupier health and comfort and to minimize long-term risks to property values and investments. The scope of this MO consists of actions at building level to adapt and ensure resilience to the following risks:

- increased overheating in summer and inadequate heating in winter, which could lead to discomfort and be detrimental to health,
- increased risk of extreme weather events, which could compromise the security and integrity of building elements, and
- increased risk of flood events, which could overwhelm drainage systems and damage structures and materials.

The core KPIs taken into account by this MO are the next ones:

- Protection of occupier health and thermal comfort. This indicator makes use of the same methodology described for indicator 4.2, with the difference being that instead of using present and past weather as the basis for modelling performance, it encourages users to use projections for future climates in 2030 and 2050 under different “degree scenarios”.

- Increased risk of extreme weather events accordingly to Level 1 checklist;
- Increased risk of flood events accordingly to Level 1 checklist.

Even if the most of frameworks identified don't address the goals of the MO5 as it is wider, some KPIs are closely related to this level. It is given in the Table 10.

Table 10. KPIs related to the MO5 of the LEVEL framework

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Environment and built environment	Bioclimatic needs (Bbio (points))	This indicator from the French Environmental regulation RE2020 is defined as the energy needs for the heating, cooling and indoor lighting of one building. It characterizes the capacity of a building to reduce heating needs during the winter, cooling needs during the summer and indoor lighting needs. To be regulatory, the value of the Bbio of a building must not exceed the value of the Bbio_max Bbio_max	Bbio_max average: value of the Bbio_max requirement for an average building, depending on the use of the building or part of the building; Mbgéo and Mcgéo and Migéo: modulation coefficient according to the geographical location (geographical area and altitude) of the building; Mbcombles and Mccombles and Micombles: modulation coefficient according to the floor area of the converted attic of the building or part of the building, for individual houses; Mbsurf_moy and Mcsurf_moy and Misurf: modulation coefficient according to the average surface of the dwellings of the building or the part of the building, for the buildings with residential use; Mbsurf_tot: modulation coefficient according to the reference area of the building or part of the building; Mbnoise: modulation coefficient according to the exposure of the building or part of the building to the noise of transport infrastructures in the vicinity of the building.	Bbio < Bbiomax Bbiomax = Bbio_maxaverage × (1 + Mbgéo + Mbcombles + Mbsurf_moy + Mbsurf_tot + Mbnoise)

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Environment and built environment	Ic energy Impact on climate change associated with primary energy consumption (kg eq. CO_2/m^2)	This indicator from the French Environmental regulation RE2020 is the indicator which characterizes the impact on climate change of primary energy consumption over the life of the building, i.e. 50 years	Additionnal to the Bbio calculation data points: Mcsurf_tot: modulation coefficient according to the total surface of the building for collective dwellings. Mccat: modulation coefficient according to the category of external constraints of the building. Mccat allows to compensate the external constraints that limit the natural ventilation possibilities of the building by opening the windows (Br2, Br3), when it requires the use of an air-conditioning system for the buildings around and behind the buildings.	Ic energy < Ic energy max Ic energy max= Ic energy_maxaverage × (1 + Mcgéo + Mccombles + Mcsurf_moy + Mcsurf_tot + Mccat)
Environment and built environment	Ic construction Impact on climate change associated to "components + "construction site (kg eq. CO_2/m^2)	This indicator from the French Environmental regulation RE2020 is the indicator which characterizes the impact of building components (materials and equipment) and the construction site on climate change.	Additional to the Bbio calculation data points: Miinfra: modulation coefficient according to the impact of the foundations and basement spaces of the building; Mivrd: modulation coefficient according to the impact of the road and various networks of the building; Mided: modulation coefficient according to impact of the environmental default data and lump-sum values in the building evaluation. This modulation allows the adjustment of requirements to take into account the lack of availability of specific environmental data.	Ic construction < Ic construction max Ic construction max= Ic construction_maxaverage × (1 + Micombles + Misurf) + Miinfra + Mivrd + Migéo + Mided)
Comfort conditions / Environment and built environment	Eutrophication, acidification, toxicological stress on human health and	This KPI is part of the LCA which addresses the environmental aspects and potential environmental impacts throughout a product's	ISO 14044:2006 EN 15978:2011 EN 15804:2012	Application of relevant software is needed – Results to be aligned with ISO 14044:2006

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
	ecosystems (N/A)	life cycle from raw material acquisition to the final disposal. This KPI focuses on the human and the ecosystem.		
Environment and built environment	Soil permeability (%)	Minimize disruption and pollution of natural water flows.	Data from Building owner, construction company	Quantity of permeable external surfaces compared to the total external surfaces pertaining to the building (C.4.3 from ITACA).
Environment and built environment	Integration with the natural and built environment (N/A)	This indicator from the ITACA protocol - buildings is part of the "External environmental quality" category. This KPI measures the integration of the asset with the natural and built environment.	Data available within SBTool (tool of the ITACA Protocol- buildings).	Need to apply the SBTool model.
Comfort conditions	Heat island effect (%)	Ensure that outdoor spaces have conditions of acceptable thermal comfort during the summer. This indicator is presented in UNI/TS 11820:2022 and in ITACA protocol.	Verification documents (such as the MEC Report, products certifications and so on), Outdoor temperature (°C)	Ratio between the area of surfaces capable of decreasing the heat island effect compared to the overall area of the intervention (external surfaces of relevance + coverage) (C.6.8 from ITACA).
Resource use	Use of local tree species (%)	Encourage the use of native tree species.	Data from Building owner, construction company	Percentage between the number of plants of native species planted and the total number (A.3.7 from ITACA).

Some of the KPIs related to this MO5 are also considered inside the MO4. This is the case for 2 KPIs Summer Degree-hour of discomfort (DH (°C.h)) and Summer Comfort (N/A) which are already described in the MO4.

4.1.6 LEVEL MACRO-OBJECTIVE 6

The Macro-Objective 6 aims to optimize the life cycle cost and value of buildings to reflect the potential for long-term performance improvement, inclusive of acquisition, operation, maintenance, refurbishment, disposal and end of life. It considers actions and decision-making at building level that are based on a long-term view of the whole life costs and market value of more sustainable buildings, including:

- achieving lower life-cycle costs and more productive and comfortable spaces to live and work in, and
- having a positive influence on property market value appraisals and risk ratings.

The core KPIs considered by this MO6 are the next ones:

- Life cycle costs in €/m^2/yr;
- Value creation and risk exposure accordingly to Level 1 checklist.

The KPIs from the section 3 related to the MO6 are given in the Table 11.

Table 11. KPIs related to the MO6 of the LEVEL framework

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Economics	SRI score (%)	Described in the MO1	Described in the MO1	Described in the MO1
Economics	Payback Period (year)	The term payback period refers to the amount of time required to recover the project investment by project profits	Investor, building owners	Payback time= Initial investment/ Net annual cash flow (i.e., energy savings)
Economics	Return on investment (ROI), (%)	Return on investment (ROI) is a performance measure used to evaluate the efficiency or profitability of an investment or compare the efficiency of a number of different investments. ROI measures the amount of return on a particular investment, relative to the investment's cost.	Investor, building owners	ROI= [Money saved from the renovation (i.e., energy savings) / Cost of investment] x 100.
Economics	Internal rate of return (%)	The internal rate of return is the interest rate at which the net present value of all the cash flows from the retrofit project equal zero.	Investor, building owners	Internal Rate of return= [(Current Value− Initial value) / Initial value] ×100
Economics	Investment cost (€)	Investment cost means the Contract Purchase Price of Investments acquired, Acquisition Expenses, capital expenditures and other customarily capitalized costs, but excludes Acquisition Fees.	Data available from the investor/ building owner/etc.	Total investment costs (€*) = ∑investments on renovation

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Economics	Normalized investment cost (€/m²)	Total amount of money spent for the retrofit project per square meter	Data available from the investor/ building owner/etc.	Normalized investment cost = ΣInvestments on renovation of project (€*) / ΣUnits and/or m² renovated
Economics	Life cycle cost – LCC (€/m²/y)	The LCC is the sum of all recurring and one-time costs of the retrofit project over the full life span.	ISO 15686-5 EN 15643-4 EN 16627:2015	Application of relevant software is needed – Results to be aligned with ISO 15686-5
Economics	Annual energy cost estimation (€/year)	The sum of the cost from the energy consumption of the building after the retrofit.	Data from Building owners (i.e., energy bills, etc.)	
Economics	Cost efficiency of the energy consumption ((kWh/yr) / k€)	Energy consumption saved for each thousand € invested in energy renovation	Data from Building owners, investor (i.e., electric bills, costs, etc.)	=∑Final energy consumption reduction in kWh/year / ∑Investment in energy renovation /1000
Economics	Financial savings from energy renovation (€)	Total financial cost savings for end-users per year based on savings on heating, cooling and DHW, carbon tax (when applicable), and the usable contribution from renewable energy systems.	Building owners	Total financial savings from energy renovations = ∑financial savings from energy renovations completed projects

4.1.7 KPIS OUTSIDE OF THE ACTUAL SCOPE OF THE LEVEL FRAMEWORK

In this section the KPIs considered are mainly related to the Social/user's behaviour and Environment and built environment categories (see Table 12). Currently these KPIs are not taken into consideration in the scope of LEVEL(s) framework.

Table 12. KPIs outside of the actual scope of the LEVEL framework

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Environment and built environment	Land reuse (N/A)	Encourage the use of contaminated, abandoned or previously anthropized areas.	Data from municipality, construction company	Level of previous use of the area of intervention (A.1.5 from ITACA).

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Social/user's behaviour	Equipped outdoor areas for common use (N/A)	Encourage the use of outdoor spaces of common use pertaining to the building.	Data from building owner, construction company	Service level of the common outdoor areas pertaining to the building (A.3.3 from ITACA).
Social/user's behaviour	Support for the use of bicycles (%)	Encourage the installation of bicycle parking spaces.	Data from building owner, construction company	Percentage between the number of bicycles that can actually be parked in a functional and safe way and the number of users of the building (A.3.4 from ITACA).
Social/user's behaviour	B.A.C.S. and Home automation systems (N/A)	Increase the level of energy saving, safety and comfort of users.	Data from building owner, construction company	Number of home automation functions implemented (E.3.5 and E.3.6 from ITACA).
Social/user's behaviour	Design for all (%)	Guarantee also to people with reduced or impeded motor or sensory capacity to reach the building, in its individual real estate and environmental units, to enter it easily and to use spaces and equipment in conditions of adequate safety and autonomy.	Data from building owner, construction company	Percentage of improvement solutions in the technical documentation relating to the accessibility and usability of the school building (E.7.1 from ITACA).
Social/user's behaviour	Availability of technical documentation of buildings (N/A)	Presence and characteristics of the technical documentation of buildings.	Data from building owner, construction company	E.6.5 from ITACA
Social/user's behavior	Arrears on utility bills	Diverse set of indicators for portraying the different dimensions of energy poverty at city/territory scale, including quantitative and qualitative indicators [9]	Household income, housing-related data, energy prices, energy expenditure data	The arrears on utility bills indicator represents the share of (sub-) population/ households with arrears on utility bills, based on the question "In the last twelve months, has the household been in arrears, i.e., has been unable to pay on time due to financial difficulties for utility bills (heating, electricity, gas, water, etc.) for the main dwelling?".
Social/user's behavior	Inability to keep home adequately warm		Household income, housing-related data, energy prices, energy expenditure data	The inability to keep home adequately warm indicator represents the share of (sub-) population /households not able to keep their home adequately warm, based

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
				on the question "Can your household afford to keep its home adequately warm?".
Social/user's behavior	High share of energy expenditure in income (2M)		Household income, housing-related data, energy prices, energy expenditure data	The 2M indicator represents the proportion of households whose share of energy expenditure in income is more than twice the national median.
Social/user's behavior	Low absolute energy expenditure (M/2)		Household income, housing-related data, energy prices, energy expenditure data	The M/2 indicator represents the share of households whose absolute energy expenditure is below half the national median or, in other words, abnormally low.
Social/user's behavior	Pop. Liv. dwelling with presence of leak, damp and rot		Household income, housing-related data, energy prices, energy expenditure data	The Pop. Liv. dwelling with presence of leak, damp, and rot indicator represents the share of the population with a leak, damp or rot in their dwelling, based on the question "Do you have any of the following problems with your dwelling/accommodation" • a leaking roof • damp walls/floors/ foundation • rot in window frames or floor
Social/user's behavior	At Risk of Poverty or Social Exclusion		Household income, housing-related data, energy prices, energy expenditure data	The "at risk of poverty or social exclusion" indicator represents the people at risk of poverty or social exclusion (% of the population).
Social/user's behavior	Dwellings with energy label A		Household income, housing-related data, energy prices, energy expenditure data	The "dwellings with energy label A" indicator represents the share of dwellings with an energy label A.

4.2 RENOVATION PACKAGES PERFORMANCE KPIS

The Built4People partnership and the Renovation Wave highlight the need of comprehensive, certified, industrialized and market-ready multifunctional solutions, with passive and active features, as prefabricated turnkey packages (components or groups of systems/components) to enable cheaper and quicker renovations with limited impact on the residents. The REHOUSE project addresses these aspects by introducing the term “Renovation package” (RP) which is composed by a set of innovative components validated at lab scale and designed following circularity, prefabrication and multi-functionality principles. The RP’ components fit within:

- Technologies that reduce energy demand.
- Technologies that improve energy efficiency.
- Technologies that improve building operations.
- Technologies that reduce the construction waste.

8 RPs are planned to be demonstrated in operational environment (TRL7) in REHOUSE.

For these RPs the next KPIs have been identified. One part of the KPIs have already been described into the Grant Agreement (Impact section), another part of the KPIs have been discovered during the benchmark works. For these KPI the next categories have been introduced:

- Technical: covering aspects such as Energy efficiency, flexibility, and time savings on-site.
- Environmental: covering aspects such as GHG, waste savings.
- Economic: as for example Cost savings.
- Social: covering aspects such as Comfort, user acceptance.

The synthesis of these KPIs is given in the Table 13.

Table 13. Synthesis of KPIs for renovation packages performances assessment

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Economic	KPI01: Renovation work time reduction demonstrated against current practices [%]	This KPI represents a potential reduction of the renovation duration using renovation packages compared with renovation using similar products. It leads to a related and immediate increase of productivity.	Renovation work time using renovation packages [Time unit: Month, Day, Hour, etc.]; Renovation work time using similar products [Time unit: Month, Day, Hour, etc.]	(Renovation work time using similar products-Renovation work time using renovation packages)/Renovation work time using similar products
Technical	KPI02: Insulation improvement against standards [%]	This KPI quantifies the improvement in terms of insulation using the RPs compared to standard renovation solutions.	Thermal transmittance using the Renovation Package [W/m^2·K] Thermal transmittance from standard solutions, normative, or baseline	(Thermal transmittance from standard solutions – Thermal transmittance using RPs)/Thermal transmittance from standard solutions

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
			status [W/m²·K]	
Technical	KPI03: Air tightness improvement against standards [%]	This KPI quantifies the improvement in terms of air-tightness using the RPs compared to standard renovation solutions.	Air tightness using the Renovation Package [ACH; vol/h; m³/h·m²] Air tightness from standard solutions, normative or baseline status [ACH; vol/h; m³/h·m²]	(Air tightness from standard solutions – Air tightness using RPs)/Air tightness from standard solutions
Social	KPI04: Reduction in the Predicted Percentage of Dissatisfied people during occupancy hours [%]	This KPI quantifies the reduction of dissatisfied people by applying the RPs during occupancy hours in terms of thermal comfort	Average PPD during occupancy hours after RP implementation [%] Average PPD during occupancy hours before the implementation of the RP [%]	(Average PPD before RP – Average PPD after RP)/Average PPD before RP
Social	KPI05: Improvement in terms of PMV [Predicted Mean Vote]	This KPI calculates the improvement of Predicted Mean Vote in terms of thermal comfort	PMV after the RP implementation [PMV] PMV before the RP implementation [PMV]	(PMV before RP – PMV after RP)/PMV before RP
Social	KPI06: Reduction in the Sound pressure level in occupied spaces [%]	This KPI quantifies the reduction in terms of sound pressure level in occupied spaces by applying the RPs	SPL after the RP implementation (dBA) SPL d before the RP implementation (dBA)	(SPL before RP – SPL after RP)/SPL before RP
Social	KPI07: Reduction in the average CO_2 concentration during occupancy hours [%]	This KPI quantifies the reduction in the CO_2 concentration during occupancy hours by applying the RPs	CO_2 concentration after the RP implementation (ppm) CO_2 concentration before the RP implementation (ppm)	(CO_2 concentration before RP – CO_2 concentration after RP)/CO_2 concentration before RP
Social	KPI08: Reduction in the average Formaldehyde and VOCs concentration [%]	This KPI quantifies the reduction in the formaldehyde and VOCs concentration by applying the RPs	Formaldehyde and VOCs concentration after the RP implementation (µg/m³; ppm) Formaldehyde and VOCs concentration before the RP implementation (µg/m³; ppm)	(Formaldehyde and VOCs concentration before RP – Formaldehyde and VOCs concentration after RP)/ Formaldehyde and VOCs concentration before RP

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Social	KPI09: Reduction in the TVOC concentration (Total Volatile Organic Compound) [%]	This KPI quantifies the reduction in the TVOC concentration by applying the RPs	TVOC concentration after the RP implementation (µg/m^3; ppm) TVOC concentration before the RP implementation (µg/m^3; ppm)	(TVOC concentration before RP – TVOC concentration after RP)/ TVOC concentration before RP
Social	KPI10: Reduction in CO, PM concentration [%]	This KPI quantifies the reduction in the CO, PM concentration by applying the RPs	CO, PM concentration after the RP implementation (µg/m^3; ppm) CO, PM concentration before the RP implementation (µg/m^3; ppm)	(CO, PM concentration before RP – CO, PM concentration after RP)/ CO, PM concentration before RP
Economic	KPI11: Reduction of the Investment cost [%]	This KPI quantifies the reduction of the investment cost of the RPs compared with BAU references for similar solutions	Investment cost of the RP [€, €/m^2, €/kW, etc.] Investment cost of similar solutions [€, €/m^2, etc.]	(Investment cost of similar solutions – Investment cost of the RP)/Investment cost of similar solutions
Technical	KPI12: Energy demand reduction [%]	This KPI quantifies the energy demand reduction by implementing the RPs	Energy demand before the implantation of RP [kWh/m^2] Energy demand after the implantation of RP [kWh/m^2]	(Energy demand before RP – Energy demand after RP)/Energy demand before RP
Technical	KPI13: Increase of RES demonstrated against regulations requirements [%]	This KPI quantifies the increase of RES production compared to regulations	RES production with the RPs [kWp/m^2] RES requirements based on regulations [kWp/m^2]	(RES by RPs – RES by regulations)/RES by RPs
Technical	KPI14: Embodied energy reduction [%]	This KPI quantifies the reduction of the embodied energy comparing the RPs to conventional solutions	Total embodied energy includes [MJ/m^2]: · Energy to produce the materials/ components of the solution. · Energy to transport the materials/ components of the solution to the site. · Energy used on-site during the renovations.	(Embodied energy of the conventional solution – Embodied energy of the RP)/Embodied energy of the conventional solution EPC (Energy Performance Certificates)

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
			The above aspects should be collected for the RPs and for the conventional solution.	
Environmental	KPI15: GHG emissions reduction across the lifecycle [%]	This KPI quantifies the GHG emissions reduction across the lifecycle of the innovation comparing to best performing solutions already available on the market	LCA of the RP [gCO_2eq/kWh; kgCO_2eq/m^2] LCA of a conventional solution available in the market [gCO_2eq/kWh; kgCO_2eq/m^2] It covers: Embodied CO_2 and Operational CO_2	LCA assessment
Technical	KPI16: Increase of RES power at demo-site level [%]	This KPI quantifies the increase of renewable energy generation solutions for on-site multipurpose (heating, cooling, electricity)	RES power after the integration of RP [kW/m^2, kWp/m^2] RES power before integration of RP [kW/m^2, kWp/m^2]	(RES power after RP – RES power before RP)/RES power after RP
Environmental	KPI17: % of bio-sourced materials [%]	This KPI quantifies the percentage of bio-sourced materials in the RP	Amount of bio-sourced materials in the RP [kg, m^3, etc.] Amount of bio-sourced materials in the RP [kg, m^3, etc.]	Amount of bio-sourced materials in the RP/ Amount of bio-sourced materials in the RP
Environmental	KPI18: % of reused components [%]	This KPI quantifies the percentage of reused components in the RP	Amount of reused components in the RP [nº] Total amount of components in the RP [nº]	Amount of reused components in the RP/ Total amount of components in the RP
Environmental	KPI19: % of recycled material [%]	This KPI quantifies the percentage of recycled materials in the RP	Amount of recycled materials in the RP [kg, m^3, etc.] Total amount of materials in the RP [kg, m^3, etc.]	Amount of recycled materials in the RP/ Total amount of materials in the RP
Environmental	KPI20: % of recyclability of the package [%]	This KPI quantifies the percentage of recyclability of the RP	Amount of components with potential to be recycled in the RP [nº] Total amount of components in the RP [nº]	Amount of components with potential to be recycled in the RP/ Total amount of components in the RP

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Economic	KPI21: Estimated time for a fully certified product [time unit]	This KPI estimates the time for a fully certified RP being ready for the market roll-out	Estimation of the time to have a fully certified RP [time unit: months, years]	Estimation of the time to have a fully certified RP
Comfort conditions / Environment and built environment	Eutrophication, acidification, toxicological stress on human health and ecosystems (N/A)	This KPI is part of the LCA which addresses the environmental aspects and potential environmental impacts throughout a product's life cycle from raw material acquisition to the final disposal. This KPI focuses on the human and the ecosystem.	ISO 14044:2006 EN 15978:2011 EN 15804:2012	Application of relevant software is needed – Results to be aligned with ISO 14044:2006

4.3 CITY AND TERRITORY KPIS

The next KPIs concern mainly cities and territories/countries. One part of these are the building KPIs which are also applicable at the city and territory scale:

- Renewable energy production in kWh or in %. If the KPI is expressed in %, it could be assessed as the percentage of total energy derived from renewable sources, as a share of the city's total energy consumption, as defined by the European Telecommunications Standards Institute (ETSI).
- Share of renewable energy (%) which is a total share of renewable energy sources in a complex energy supply system at city scale.

Another part of these are the KPIs proper to city and territory scale. These ones are given in the Annex V: City and territory KPIs. The biggest part of these KPIs is provided by the Italian ITACA protocol at urban scale for the evaluation of environmental sustainability of urban contexts. This protocol is useful for public planning bodies and all those stakeholders in developing or transforming urban areas in order to implement its use also in support of financing programs at national level for urban regeneration. The macro themes considered by ITACA protocol at urban scale on which the evaluation is based concern governance, including the participatory process, city planning aspects, urban landscape quality, architectural aspects, public spaces, urban metabolism, biodiversity, adaptation, mobility and accessibility, society and culture, economy.

5 CONCLUSIONS

This deliverable is completed in the context of the WP3 Task 3.1 of the REHOUSE project. It provides useful material for the definition of the KPIs for the evaluation of demonstration sites and

RPs' performances in the task 3.2 and for the definition of social assessment methods in the WP1.

The information included in the present deliverable summarizes the results of the bibliographic review at European and international scale, as well as the experience feedback from project partners relative to frameworks for MEL (Monitoring, Evaluation and Learning). It establishes a basis for a global multi-sectorial assessment of building renovation processes through the definition of KPIs at building and RPs' scale.

The European framework LEVEL(s) has been selected as the starting point for the identification of the KPIs for building performances evaluation across 6 Macro-objectives:

- MO1 – Greenhouse gas and air pollutant emissions along a building's life cycle.
- MO2 – Resource efficient and circular material life cycles.
- MO3 – Efficient use of water resources.
- MO4 – Healthy and comfortable spaces.
- MO5 – Adaptation and resilience to climate change.
- MO6 – Optimized life cycle cost and value.

Several frameworks and protocols covering all or almost all of the core indicators of these MO have been identified. Between them the SRI framework for rating the smart readiness of buildings, Italian ITACA protocol for assessment of the level of energy and environmental sustainability of buildings, SMARTENCITY project to generate a complete set of indicators to measure the impact of project actions at city and action levels and some others.

The KPIs identified allow to evaluate the impact of building renovations by comparisons between before and after the implementation of some ECMs and by comparison with some standardized or reference target values based on local regulations and international standards ISO or results of modelling processes. Also, the calculation formulas and assessment methods for the same KPIs are often adapted to a geographical area where they are implemented.

Special attention has been paid to social frameworks allowing to evaluate the impact of building renovation on different stakeholders: workers, local community, society, consumers and value-chain actors. The additional KPIs - results of the bibliographic review augmenting these ones of the LEVEL(s) are mostly belonging to social and Environment/built environment domains. To be more in adequacy with the project goals the KPIs identified have been categorized by more precise categories which are: building envelope, resource use, comfort conditions, economics, social/user's behaviour, environment and built environment, and resources re-use. Such categorization will allow rapid definition of a final set of KPIs for the REHOUSE project.

The KPIs for the evaluation of the RPs are the ones identified in the Grant Agreement. The bibliographic review allowed also to identify additional KPIs for evaluation of RPs performances, as well as these ones for evaluation at urban scale. The biggest part of KPIs for evaluation at urban scale can't be directly used to building scale evaluation, but some of them could be downscaled at smaller scale and so potentially used in the REHOUSE project.

According to the interest of the relevant stakeholders, which are the demonstration sites managers and renovation packages leaders, some of these KPIs will be directly applied to the evaluation procedures, some of them will be updated to be more in adequacy with renovation processes.

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7 ANNEXES

7.1 ANNEX I: REGIONAL/ NATIONAL/ INTERNATIONAL REGULATIONS AND STANDARDS

As mentioned in section 3, the Annex I reports the lists of KPIs and their categories and/or sub-categories for the Italian regulation (GPP and ITACA-Protocol for buildings) as well as the international, European and BREEAM standards.

ITALIAN GPP COMPULSORY MINIMUM ENVIRONMENTAL CRITERIA (MEC): List of categories and KPI

Due to complexity and number of KPIs the Table 14 gives only the information about categories and sub-categories of KPIs used. More detailed information is available on the GPP website https://gpp.mite.gov.it/PDF/GURI%20183%2006.08.22%20-%20Allegato%20Edilizia.pdf.

Table 14. The categories and sub-categories of the Italian GPP Compulsory MEC

Categories	KPIs Sub-categories	Description of subcategories
2.1 Selection of candidates		environmental management systems
2.2 Contractual conditions		for designers
2.3 Technical Specification for groups of buildings		
	2.3.1 Natural and landscape integration	
	2.3.2 Permeability of the land area	
	2.3.3 Reduction of the summer heat island effect and air pollution	
	2.3.4 Reduction of the impact on the surface and underground water system	
	2.3.5 Primary infrastructure 2.3.5.1 Collection, purification, and reuse of rainwater 2.3.5.2 Irrigation network for public green areas 2.3.5.3 Areas equipped for separate waste collection 2.3.5.4 Public lighting system 2.3.5.5 Sub-services for technological infrastructure	
	2.3.6 Secondary infrastructure and sustainable mobility	
	2.3.7 Energy supply	
	2.3.9 Water saving	
2.4 Technical Specification for buildings		
	2.4.1 Energy Diagnosis	
	2.4.2 Energy performance	ensure adequate thermal comfort conditions through one of the following options: Surface mass, transmittance values or room occupancy hours

Categories	KPIs Sub-categories	Description of subcategories
	2.4.3 Indoor lighting systems	
	2.4.4 Inspection and maintenance of heating and air conditioning systems	
	2.4.5 Ventilation, ventilation and air quality	
	2.4.6 Thermal comfort	PMV and PPD
	2.4.7 Natural lighting	Calculation are indicated within UNI EN 17037
	2.4.8 Shading devices	
	2.4.9 Air tightness	n50 values to be verified according to UNI EN ISO 9972
	2.4.10 Indoor electromagnetic pollution	
	2.4.11 Acoustic performance and comfort	
	2.4.12 Radon	Metres for monitoring the value does not exceed the limit of 200 Bq/m3
	2.4.13 Building maintenance plan	
	2.4.14 Disassembly and end of life	
2.5 Technical Specification for building components		Generally related to the content of recycle material
	2.5.1 Emissions in confined spaces (indoor pollution)	Emission determination according to UNI EN 16516 o UNI EN ISO 16000-9
	2.5.2 On-site and ready-mixed concretes	
	2.5.3 Precast concrete, aerated autoclaved concrete and vibrated concrete products vibro-compressed concrete	
	2.5.4 Steel	
	2.5.5 Bricks	
	2.5.6 Wood products	
	2.5.7 Thermal and acoustic insulation products	A list of requirements to be compliant with is provided in the document
	2.5.8 Partitions, perimeter walls and false ceilings	
	2.5.9 Stone and mixed masonry	
	2.5.10 Flooring	
	2.5.11 PVC windows and shutters	
	2.5.12 PVC and polypropylene pipes	
	2.5.13 Paints and varnishes	
2.6 Technical Specification of the building site		
	2.6.1 Site Environmental Performance	
	2.6.2 Selective demolition, recovery and recycling	
	2.6.3 Ground surface layer preservation	

Categories	KPIs Sub-categories	Description of subcategories
	2.6.4 Backfills	
2.7 Award criteria		not mandatory, integrative criteria for most economically advantageous tenders
	2.7.1 Technical competence of designers	
	2.7.2 Methodologies for optimising design solutions for sustainability (LCA and LCC)	
	2.7.3 Design in BIM	
	2.7.4 Assessment of non-financial risks or ESG (Environment, Social, Governance)	
2.8 Performance conditions		contractual clauses for building company

ITACA Protocol – Buildings: Categories and KPIs

Categories	KPIs (units)	Description
Area A – Site quality	A.1.5 Land reuse	Encourage the use of contaminated, abandoned or previously anthropized area
	A.1.6 Accessibility to public transport	Encourage the choice of sites from which public transport networks are easily accessible to reduce the use of private vehicles
	A.1.8 Functional mix of the area	Encourage the choice of spaces located near areas characterized by an adequate functional mix
	A.1.10 Adjacency to infrastructures	Promote the construction of buildings near infrastructure networks to avoid environmental impacts caused by the construction of new connections
	A.3.3 External areas of equipped common use	Encourage the use of common outdoor spaces pertaining to the building
	A.3.4 Support for the use of bicycles	Encourage the installation of bicycle parking spaces
	A.3.7 Use of local tree species	Promote the use of non-invasive tree and shrub species, improve the environmental benefits in the design of external arrangements by reducing water requirements, use local or naturalized plant species
	A.3.10 Support for green mobility	Encourage the use of vehicles with a reduced environmental impact
Area B – Resource consumption	B.1.2 Non-renewable primary energy	Improve the energy performance of the building with the reduction of non-renewable primary energy during the operational phase of the building
	B.1.3 Total primary energy	Improve the energy performance of the building by reducing the total primary energy during the operational phase of the building
	B.3.2 Renewable energy for thermal uses	Promote the production of energy from renewable sources.
	B.3.3 Energy produced on site for electrical use	Encourage the use of electricity produced from sources renewable
	B.4.1 Reuse of existing	Promote the reuse of existing buildings, discourage the

Categories	KPIs (units)	Description
	structures	demolition of buildings in the presence of recoverable structures
	B.4.6 Recycled/recovered materials	Encourage the use of recycled and recovered materials to reduce the consumption of new resources
	B.4.7 Materials from renewable	Promote the use of materials from renewable sources
	B.4.8 Local materials	Promote the procurement of local materials
	B.4.10 Materials that can be disassembled	Promote a design that allows disassembly of components so that they can be reused or recycled
	B.4.11 Certified materials	Encourage the use of construction products with certifications or declarations
	B.5.1 Potable water for irrigation	Reducing water consumption for irrigation through water recovery or optimization strategies
	B.5.2 Potable water for indoor use	Reducing water consumption for indoor use through water recovery or optimization strategies
	B.6.1 Useful thermal energy for heating	Reduce the need for useful energy for heating during the operational phase of the building
	B.6.2 Useful thermal energy for cooling	Reduce the need for useful energy for cooling during the operational phase of the building
	B.6.3 Global average heat transfer coefficient	Reduce the heat exchange by transmission during the winter period
	B.6.4 Control of solar radiation	Reduce solar gains in the summer
Area C - Environmental loads	C.1.2 Emissions expected in the operational phase	Reduce the amount of CO2 equivalent emissions from non-renewable primary energy used for the building's annual operation
	C.3.2 Solid waste produced in the operational phase	Encourage separate collection of solid waste
	C.3.3 Reuse of land	Promote the reuse of excavated earth on site
	C.4.1 Gray water sent to the sewers	Minimize the amount of effluent discharged into the sewer
	C.4.3 Soil permeability	Minimize disruption and pollution of natural water flows
	C.6.8 Heat island effect	Ensure that outdoor spaces have acceptable thermal comfort conditions during the summer
Area D - Indoor environmental quality	D.2.1 Effectiveness of natural ventilation	Ensure natural ventilation that maintains an acceptable indoor air quality (IAQ) for the user
	D.2.2 Air quality and mechanical ventilation	Ensure mechanical ventilation that maintains an acceptable indoor air quality (IAQ) for the user
	D.2.6 Radon	Minimize exposure to radon by controlling its migration from soils to indoor environments
	D.3.1 Summer thermal comfort in air-conditioned rooms	Ensuring a satisfactory level of summer thermal comfort in rooms with an air conditioning system
	D.3.2 Operating temperature in the summer period	Maintain a satisfactory level of thermal comfort during the summer period
	D.3.3 Winter thermal comfort in air-conditioned rooms	Ensuring a satisfactory level of winter thermal comfort in rooms with an air conditioning system
	D.4.1 Natural lighting	Ensure an adequate level of natural lighting in the main

Categories	KPIs (units)	Description
		rooms
	D.5.5 Reverberation time	Ensure adequate acoustic correction of sound reverberation in main rooms
	D.5.6 Acoustic quality of the building	Protection from external and internal noises of the building
	D.6.1 Industrial frequency magnetic fields (50 Hertz)	Minimize the level of electric and magnetic fields at industrial frequency (50 Hz) in internal environments in order to reduce exposure of individuals as much as possible
Area E - Quality of service	E.2.1 Provision of functional spaces	Ensure good functionality in the structure with adequate external and internal spaces
	E.3.5 B.A.C.S.	Increase the level of energy savings, safety and user comfort
	E.3.6 Consumption monitoring	Monitor energy consumption to optimize systems and provide information to occupants and energy managers on the use of energy in the building with real-time data obtained from sensors
	E.6.5 Availability of the technical documentation of the buildings	Optimize the operation of the building and its technical systems
	E.6.6 Availability of the technical documentation of the buildings - B.I.M.	Optimize the management of the building and its technical systems in the life cycle
	E.7.1 Design for all	Also guarantee people with reduced or impaired motor or sensory ability to reach the building, in its individual units, to enter it easily and to use its spaces and equipment in conditions of adequate safety and autonomy

International (ISO) and European (EN) standards description:

ISO 14040:2006: Environmental management – Life cycle assessment – Principles and frameworks and ISO 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines

Description and objectives:

To assess the environmental impacts from a life cycle perspective (LCA). LCA addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave).

Classifies the impacts into 12 categories: Climate change, stratospheric ozone depletion, tropospheric ozone (smog) creation, eutrophication, acidification, toxicological stress on human health and ecosystems, and the depletion of resources, among others

Reference:

https://www.iso.org/obp/ui#iso:std:iso:14040:ed-2:v1:en

ISO 15686-5:2017: Buildings and constructed assets – Service life planning – Life cycle costing

Description and objectives:

Provides requirements and guidelines for performing life-cycle cost (LCC) analyses of buildings and constructed assets and their parts, whether new or existing.

Life cycle cost is a valuable technique that is used for predicting and assessing the cost performance of constructed assets.

Reference:

https://www.iso.org/obp/ui/#iso:std:iso:15686:-5:ed-2:v1:en

ISO/CD 14075: Principles and framework for social life cycle assessment

Description and objectives:

This ISO is under development. Assess the social impacts from a Life Cycle perspective.

Reference:

https://www.iso.org/standard/61118.html

ISO 7730:2005 Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria

Description and objectives:

Presents methods for predicting the general thermal sensation and degree of discomfort (thermal dissatisfaction) of people exposed to moderate thermal environments. It enables the analytical determination and interpretation of thermal comfort using calculation of PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) and local thermal comfort, giving the environmental conditions considered acceptable for general thermal comfort as well as those representing local discomfort.

Reference:

https://www.iso.org/standard/39155.html

ISO 16813:2006: Building environment design – Indoor environment – General principles

Description and objectives:

Establishes the general principles of building environment design taking into account healthy indoor environment for the occupants, and protecting the environment for future generations. ISO16813:2006 promotes an approach in which the various parties involved in building environmental design collaborate with one another to provide a sustainable building environment.

Reference:

https://www.iso.org/standard/41300.html

ISO 50006:2014: Energy management systems – Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) – General principles and guidance

Description and objectives:

Provides guidance to organizations on how to establish, use and maintain energy performance indicators (EnPIs) and energy baselines (EnBs) as part of the process of measuring energy performance.

Reference:

https://www.iso.org/standard/51869.html

ISO 14067:2018: Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification

Description and objectives:

This document specifies principles, requirements and guidelines for the quantification and reporting of the carbon footprint of a product (CFP), in a manner consistent with International Standards on life cycle assessment (LCA) (ISO 14040 and ISO 14044).

Reference:

https://www.iso.org/standard/71206.html

ISO 52120-1:2021: Energy performance of buildings – Contribution of building automation, controls and building management – Part 1: General framework and procedures

Description and objectives:

This document specifies:

- a structured list of control, building automation and technical building management functions which contribute to the energy performance of buildings; functions have been categorized and structured according to building disciplines and building automation and control (BAC);
- a method to define minimum requirements or any specification regarding the control, building automation and technical building management functions contributing to energy efficiency of a building to be implemented in building of different complexities;
- a factor-based method to get a first estimation of the effect of these functions on typical buildings types and use profiles;
- detailed methods to assess the effect of these functions on a given building.

Reference:

https://www.iso.org/standard/65883.html

ISO 21931-1:2022: Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 1: Buildings

Description and objectives:

This document provides a general framework for improving the quality and comparability of methods for assessing the environmental, social and economic performance of construction works, and their combination as a basis for the sustainability assessment of buildings.

Reference:

https://www.iso.org/standard/71183.html

ISO 20887:2020: Sustainability in buildings and civil engineering works — Design for

disassembly and adaptability — Principles, requirements and guidance

Description and objectives:

This document provides an overview of design for disassembly and adaptability principles and potential strategies for integrating these principles into the design process.

Reference:

https://www.iso.org/standard/69370.html

ISO 21678:2020: Sustainability in buildings and civil engineering works — Indicators and benchmarks — Principles, requirements and guidelines

Description and objectives:

This document defines principles, requirements and guidelines for the development and use of benchmarks when assessing the economic, social and/or environmental performance of buildings and civil engineering works by using sustainability indicators.

Reference:

https://www.iso.org/standard/71344.html

ISO 15392:2019: Sustainability in buildings and civil engineering works — General principles

Description and objectives:

This document identifies and establishes general principles for the contribution of buildings, civil engineering works and other types of construction works to sustainable development. It is based on the concept of sustainable development as it applies to the life cycle of construction works, from inception to the end-of-life.

Reference:

https://www.iso.org/standard/69947.html

ISO 16745-2:2017: Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 1: Calculation, reporting and communication

Description and objectives:

Provides requirements for determining and reporting a carbon metric of an existing building, associated with the operation of the building. It sets out methods for the calculation, reporting and communication of a set of carbon metrics for GHG emissions arising from the measured energy use during the operation of an existing building, the measured user-related energy use, and other relevant GHG emissions and removals.

Reference:

https://www.iso.org/standard/69969.html

ISO 21929-1:2011: Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators and a core set of indicators for

buildings

Description and objectives:

Establishes a core set of indicators to take into account in the use and development of sustainability indicators for assessing the sustainability performance of new or existing buildings, related to their design, construction, operation, maintenance, refurbishment and end of life.

Reference:

https://www.iso.org/standard/46599.html

ISO 22057:2022 Sustainability in buildings and civil engineering works — Data templates for the use of environmental product declarations (EPDs) for construction products in building information modelling (BIM)

Description and objectives:

This document provides the principles and requirements to enable environmental and technical data provided in EPDs for construction products and services, construction elements and integrated technical systems to be used in BIM to assist in the assessment of the environmental performance of a construction works over its life cycle.

Reference:

https://www.iso.org/standard/72463.html

ISO 17741:2016: General technical rules for measurement, calculation and verification of energy savings of projects

Description and objectives:

Specifies the general technical rules for measurement, calculation and verification of energy savings in retrofits projects or new projects.

Reference:

https://www.iso.org/standard/60373.html

EN 17267:2019 – Energy measurement and monitoring plan. Design and implementation. Principles for energy data collection.

Description and objectives:

This document specifies the requirements and principles for the design and implementation of an energy measurement and monitoring plan for an organization in order to improve its energy performance. The measurement and monitoring plan defines a measurement system for monitoring and analysing the energy performance of an organization, taking into account its influencing factors. This document applies to all forms of energy, to all energy uses and to all types of organizations. It does not apply to domestic dwellings.

Reference:

https://standards.cencenelec.eu/dyn/www/f?p=CEN:110:0::::FSP_PROJECT,FSP_ORG_ID:64779,2340498&cs=17CFBF7769B6B0E36CB080E4C9DD4A114

https://tienda.aenor.com/norma-une-en-17267-2020-n0064208

EN 17472:2022 – Sustainability of construction works - Sustainability assessment of civil engineering works - Calculation methods

Description and objectives:

This document establishes the requirements and specific methods for the assessment of environmental, economic and social performances of a civil engineering works while taking into account the civil engineering works' functionality and technical characteristics. By the means of this document the decision making for a project is supported by providing a standardized method for enabling comparability of scheme options. The assessment of environmental and economic performances of a civil engineering works is based on Life Cycle Assessment (LCA), Life Cycle Cost (LCC), Whole-Life Cost (WLC) and other quantified environmental and economic information. The approach to the assessment covers all stages of the civil engineering works life cycle and includes all civil engineering works related construction products, processes and services, used over its life cycle. This document is applicable to new and existing civil engineering works and refurbishment projects. The environmental performance is based on data obtained from Environmental Product Declarations (EPD) and additional indicators. This document is not applicable for the assessment of the environmental, social and economic performance of building(s) as part of the civil engineering works; instead, EN 15978, EN 16309 and EN 16627 apply.

Reference:

https://standards.cencenelec.eu/dyn/www/f?p=CEN:110:0::::FSP_PROJECT,FSP_ORG_ID:61520,481830&cs=1FDFD31DEA604833E34DE0EE14007C60E

https://tienda.aenor.com/norma-une-en-17472-2022-n0070382

EN 15643:2021 – Sustainability of construction works - Framework for assessment of buildings and civil engineering works

Description and objectives:

This document provides principles and requirements for the assessment of environmental, social and economic performance of buildings and civil engineering works taking into account their technical characteristics and functionality. NOTE 1 Assessments of environmental, social and economic performance are the three aspects of sustainability assessment of buildings and civil engineering works, or combination thereof, (hereafter referred to as "construction works"). The framework applies to all types of construction works and it is relevant for new construction works over their entire life cycle, and of existing construction works over their remaining service life and end of life stage. The sustainability assessment of construction works covers aspects and impacts of construction works expressed with quantifiable indicators. It includes the assessment of the construction works' influence on the environmental, social and economic aspects and impacts on the local area (area of influence) and of the local infrastructure beyond the curtilage of the building and the civil engineering works. NOTE 2 the sustainability assessment in the standards developed under this framework encompasses potential impacts e.g. intrinsic hazards from chemicals that are not based on a full environmental risk assessment. The assessment of environmental, social and economic aspects of organizations, such as management systems, are not included in the standards developed under this framework. However, the decisions or actions that influence the environmental, social and economic performance of the object of assessment can be taken into account where the assessment includes management process related aspects.

Reference:

https://standards.cencenelec.eu/dyn/www/f?p=CEN:110:0::::FSP_PROJECT,FSP_ORG_ID:68448,481830&cs=1DAC12E27144D55BF4417A3EEF6ABF6F0

https://tienda.aenor.com/norma-une-en-15643-2021-n0067460

EN 15804:2012+A2:2019 – Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products

Description and objectives:

This European standard provides core product category rules (PCR) for Type III environmental declarations for any construction product and construction service. NOTE the assessment of social and economic performances at product level is not covered by this standard. The core PCR: - defines the parameters to be declared and the way in which they are collated and reported, - describes which stages of a product's life cycle are considered in the EPD and which processes are to be included in the life cycle stages, - defines rules for the development of scenarios, - includes the rules for calculating the Life Cycle Inventory and the Life Cycle Impact Assessment underlying the EPD, including the specification of the data quality to be applied, - includes the rules for reporting predetermined, environmental and health information, that is not covered by LCA for a product, construction process and construction service where necessary, - defines the conditions under which construction products can be compared based on the information provided by EPD. For the EPD of construction services the same rules and requirements apply as for the EPD of construction products.

Reference:

https://standards.cencenelec.eu/dyn/www/f?p=CEN:110:0::::FSP_PROJECT,FSP_ORG_ID:70014,481830&cs=1B6FE860255B200E33E1E2E4B4A540088

https://tienda.aenor.com/norma-une-en-15804-2012-a2-2020-ac-2021-n0067399

CEN/TR 17005:2016 - Sustainability of construction works - Additional environmental impact categories and indicators - Background information and possibilities - Evaluation of the possibility of adding environmental impact categories and related indicators and calculation methods for the assessment of the environmental performance of buildings

Description and objectives:

This Technical Report (TR) has been developed by CEN/TC 350/WG 1 and WG 3 to provide a clear and structured view on the relevance, robustness and applicability of a predefined set of additional impact categories and related indicators for the assessment of the environmental performance of construction works, construction products and building materials. The TR describes the evaluation criteria that are used to determine, for these impact categories, the suitability of indicators and calculation method(s) for inclusion in the standards EN 15978 and EN 15804 (or other CEN/TC 350 standards as appropriate) in terms of their: a) relevance to: 1) the environment, 2) construction works, 3) construction products, and 4) EU policy; b) scientific robustness and certainty; and c) applicability of the impact assessment method(s). The additional impact categories examined in the TR are: - human toxicity and ecotoxicity; - particulate matter; - land use; - biodiversity; - water scarcity; and - ionizing radiation. Because EN 15978 and EN 15804 are founded on a life cycle approach, the impact categories, indicators and methods reviewed are predominantly based on their potential suitability for application in LCA. In relation to some of the areas of concern, however, where LCA methods might not be sufficiently robust or developed, some non-LCA based indicators and methods are also considered. Due to the scope of LCA used in the EN 15804 and EN 15978, impacts to users of buildings due to direct exposure to harmful emissions fall outside the scope of this TR. This falls under the scope of CEN/TC 351. Important information related to this aspect found during the development of this TR, is however mentioned in the TR. Uncertainty is an important issue in LCA. General assessment of the uncertainty related to impact assessment models is considered in the evaluation framework of this TR. However, the TR does not lay down a maximum uncertainty level to be considered acceptable in the context of the CEN standards EN 15804 and EN 15978, nor does it provide exact figures on uncertainties. Annex A of the TR provides a description of options that may be considered for incorporating selected impact categories/indicator in the standards EN 15978 and EN 15804. The TR recognizes and takes account of: - the work done by the European Commission, Joint Research Centre (EC-JRC), in the development of the International Reference Life Cycle Data System (ILCD) Handbook Recommendations, - other reports and scientific studies into the methods and application of the indicators reviewed, - findings of specific activities connected with this work such as of the CEN/TC 350 Workshop, held in Brussels on 24-25 June 2014.

Reference:

https://tienda.aenor.com/norma-cen-tr-17005-2016-41731

EN 16627:2015 – Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods

Description and objectives:

This European Standard specifies the calculation methods, based on Life Cycle Costing (LCC) and other quantified economic information, to assess the economic performance of a building, and gives the means for the reporting and communication of the outcome of the assessment. This European Standard is applicable to new and existing buildings and refurbishment projects. This European Standard gives: - the description of the object of assessment; - the system boundary that applies at the building level; - the scope and procedure to be used for the analysis; - the list of indicators and procedures for the calculations of these indicators; - the requirements for presentation of the results in reporting and communication; - and the requirements for the data necessary for the calculation. The approach to the assessment covers all stages of the building life cycle and includes all building related construction products, processes and services, used over the life cycle of the building. The interpretation and value judgments of the results of the assessment are not within the scope of this European Standard.

Reference:

https://standards.cencenelec.eu/dyn/www/f?p=CEN:110:0::::FSP_PROJECT,FSP_ORG_ID:37577,481830&cs=1B85633CE3C591EBCBA6E6B1AA9A2DDFB

https://tienda.aenor.com/norma-une-en-16627-2016-n0056237

UNE-EN 16309+A1:2014– Sustainability of construction works - Assessment of social performance of buildings - Calculation methodology

Description and objectives:

This European Standard is one part of a suite of European Standards. The standard provides the specific methods and requirements for the assessment of social performance of a building while taking into account the building's functionality and technical characteristics. This European Standard applies to all types of buildings, both new and existing. In this first version of the standard, the social dimension of sustainability concentrates on the assessment of aspects and impacts for the use stage of a building expressed using the following social performance categories (from EN 15643 3): - accessibility; - adaptability; - health and comfort; - impacts on the neighbourhood; - maintenance; - safety and security. NOTE 1 Only impacts and aspects of the above social performance categories are deemed to have an agreed basis for European standardization at this time. Two of the social performance categories included in EN 15643–3 (sourcing of materials and services and stakeholder involvement) are not deemed to be ready for standardization at this time and will be considered for inclusion in future versions of this standard (see informative Annex C). This standard does not set the rules for how building assessment schemes may provide valuation methods. Nor does it prescribe levels, classes or benchmarks of performance. Valuation methods, levels, classes or benchmarks may be prescribed in the requirements for environmental, social and economic performance in the client's brief, building regulations, national standards, national codes of practice, building assessment and certification schemes, etc. NOTE 2 Where National building regulations give minimum requirements and reference to assessment methods on these aspects, the social performance determined by assessment according to this standard can be used to determine the degree to which the building goes beyond the regulatory/legal requirements. The corporate social responsibility (CSR) of organizations is not covered by this standard. The standard gives requirements for: - the description of the object of assessment; - the system boundary that applies at the building level; - the list of indicators and procedures for the application of these indicators; - the presentation of the results in reporting and communication; - the data necessary for the application of the standard, and - verification.

Reference:

https://standards.cencenelec.eu/dyn/www/f?p=CEN:110:0::::FSP_PROJECT,FSP_ORG_ID:58840,481830&cs=14B89A93D70E7E41A62ABD5E2064B5EC9

https://tienda.aenor.com/norma-une-en-16309-a1-2015-n0054552

EN 15978:2011 – Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method

Description and objectives:

This European Standard specifies the calculation method, based on Life Cycle Assessment (LCA) and other quantified environmental information, to assess the environmental performance of a building, and gives the means for the reporting and communication of the outcome of the assessment. The standard is applicable to new and existing buildings and refurbishment projects. The standard gives: - the description of the object of assessment; - the system boundary that applies at the building level; - the procedure to be used for the inventory analysis; - the list of indicators and procedures for the calculations of these indicators; - the requirements for presentation of the results in reporting and communication; - and the requirements for the data necessary for the calculation. The approach to the assessment covers all stages of the building life cycle and is based on data obtained from Environmental Product Declarations (EPD), their "information modules" (prEN 15804) and other information necessary and relevant for carrying out the assessment. The assessment includes all building related construction products, processes and services, used over the life cycle of the building. The interpretation and value judgments of the results of the assessment are not within the scope of this European Standard.

Reference:

https://standards.cencenelec.eu/dyn/www/f?p=CEN:110:0::::FSP_PROJECT,FSP_ORG_ID:31325,481830&cs=1729D03D257298239197DBE314322D488

https://tienda.aenor.com/norma-une-en-15978-2012-n0049397

BREEAM (Building Research Establishment Environmental Assessment Method):

Categories	KPIs (units)	Description
Environmental performance	Building CO_2 ($kgCO_2eq$ pa per m_2 GIA)	The mass of CO_2 eq per square metre of the asset (GIA) arising from direct fuel use at the asset (for electricity, heating and cooling) consumed during the reporting year.
	Building CO_2 ($kgCO_2eq$ pa per FTE)	The mass of CO_2eq per Full Time Equivalent personnel employed at the asset arising from the fuel and electricity consumed by the asset during the reporting year.
	Business CO_2 ($kgCO_2eq$ pa per m^2 GIA),	The mass of CO_2eq per square metre of the asset (GIA) arising from business travel by personnel (based at the asset) and from goods (dispatched from the asset) during the reporting year.
	Staff CO_2 ($kgCO_2eq$ pa per m^2 GIA),	The mass of CO_2eq per square metre of the asset (GIA) arising from business travel by personnel (based at the asset) during the reporting year.
	Goods Transport CO_2 ($kgCO_2eq$ pa per m^2 GIA)	The mass of CO_2eq per square metre of the asset (GIA) arising from business travel associated with goods (dispatched from the asset) during the reporting year.
	Staff Commute CO_2 ($kgCO_2eq$ pa per m^2 GIA)	The mass of CO_2eq per square metre of the asset (GIA) arising from personnel travel to and from the asset during the reporting year.
	Total CO_2 ($kgCO_2eq$ pa per m^2 GIA)	Total mass of CO_2eq per square metre of the asset (GIA) arising from the fuel and electricity consumed by the asset, business travel of personnel based at the asset and transport of goods despatched from the asset, during the reporting year.
	Building Primary Energy (kWh pa per m^2 GIA)	The kilowatt hours per square metre of the asset (GIA) of fuel and electricity consumed by the asset, measured in terms of primary energy equivalent, for the reporting year.
	Water Consumption (m^3 pa per m^2 GIA)	The cubic meters of water consumed by the asset in the reporting year per square meter of the asset (GIA).
	Total Waste (tonnes pa per m^2)	The tonnes of waste removed from the asset during the reporting year per square metre of the asset (GIA).
	Proportion of Waste Recycled (%)	Percentage of total waste produced by the asset which is recycled.
	Proportion of Waste to Landfill (%)	Percentage of total waste produced by the asset which is sent to landfill.

CO_2eq: Carbon Dioxide (CO_2) equivalent: a measure of the global warming potential of different greenhouse gases in relation to that of carbon dioxide; it is defined as the amount of carbon dioxide that would give the same warming effect as that of the greenhouse gases being emitted.

$kgCO_2eq$: Mass (in kilograms) of CO_2 equivalent

pa: Per annum

GIA: Gross Internal Area: the whole enclosed area of a building within the external walls, taking each floor into account and excluding the thickness of the external walls.

FTE: Full Time Equivalent: a unit which is used to measure the people employed, or studying in a comparable way, even if they work or study a different number of hours per week. A full time employee or student is counted as 1 FTE, a part-time worker/student will be measured proportionately to the number of hours they work in comparison to a full time person.

Primary Energy: Energy which has not been subjected to any transformation or conversion process.

7.2 ANNEX II: SCIENTIFIC ARTICLES/ PROTOCOLS AND TECHNICAL STUDIES

This annex II illustrates the list of KPIs related to sub-section 3.2 Scientific articles/ Protocols and Technical studies.

Key performance indicators for holistic evaluation of building retrofits: Systematic literature review and focus group study

Categories	KPIs (units)	Description
Economics (E)	Payback period (year)	Time required to recover the project investment by project profits
	Return on investment (%)	Ratio between net profit and cost of the retrofit project
	Internal rate of return	Interest rate at which the net present value of all the cash flows from the retrofit project equal zero
	Investment cost ($)	Total amount of money spent for the retrofit project
	Normalized investment cost ($/m^2)	Total amount of money spent for the retrofit project per square meter
	Life cycle cost ($)	Sum of all recurring and one-time costs of the retrofit project over the full life span
	Increase of building value	Increase of building value
Health & safety (HS)	Ratio of actual to target number of statutory orders removed (%)	Fulfilment of the target level in removal of statutory orders over a certain period
	Ratio of actual to target number of accidents per year reduced (%)	Fulfilment of the target level in reduction of number of accidents over a certain period
Environmental (En)	Energy payback periods	Period over which the retrofitted system produces energy to recover the energy used to produce the system initially
	Energy savings (%)	Amount of energy saved as a result of the retrofit project
	Normalized energy savings (kWh/m^2 year)	Normalized energy savings (kWh/m^2 year)
	Electricity consumption per year (kWh/year)	Electricity consumption per year (kWh/year)
	Green building label	Examples of green building labels include BREEAM, LEED and BEAM Plus
Users' Perspective (U)	Target indoor air temperature (ºC)	Fulfilment of the target indoor air temperature. (For example: frequency of occurrence internal air temperatures less than or equal to 21 ºC before and after retrofit.)
	Indoor CO_2 levels/other harmful substances (ppm)	Reduction in concentration of carbon dioxide or harmful substances as a result of the retrofit project
	Target IAQ class	IAQ is generally expressed in terms of CO_2 concentration and ventilation required for reducing the concentration of indoor air pollutants. The mould growth potential (mm), indoor RH fluctuation (%), and improved percentage of complaints in air quality can also be compared before and after retrofit.
	Target work plane illuminance (lux)	The target work plane illuminance obtained as a result of the retrofit project. (e.g. recommended minimum workplace illuminance given in EN15251 for typical occupancy zones)

Categories	KPIs (units)	Description
	Target equivalent continuous weighted sound pressure level (dBA)	The target Equivalent continuous weighted sound pressure level (dBA) obtained as a result of the retrofit project's

Key Performance Indicators (KPIs) approach in buildings renovation for the sustainability of the built environment: A review of KPIs' categories and sub-categories

Categories	KPI sub-categories (units)
Economic	1.1 Direct costs 1.2 Indirect costs
Environmental	2.1 Generic 2.2 Atmosphere 2.3 Land use 2.4 Water resources 2.5 Ecology 2.6 Noise 2.7 Visual impact 2.8 Indoor quality 2.9 Energy 2.10 Reuse/Recycle 2.11 Waste management 2.12 Public health
Social	3.1 Cultural heritage 3.2 Public access 3.3 Public perception 3.4 Functionality 3.5 Occupational safety
Technological	4.1 Innovation 4.2 Intelligence 4.3 Maintenance
Time	5.1 Planning 5.2 Unexpected
Quality	6.1 Generic 6.2 Materials 6.3 Labour
Disputes	7.1 Generic site disputes
Project Administration	8.1 Contract 8.2 Procurement

UNI / TS 11820

Categories	KPIs (units)
material resources and components	by-products and/or secondary material resources (input) compared to the total material resources (input)
	Quantity of renewable or recycled material resources used for packaging related to the total packaging used

Categories	KPIs (units)
	Difference between the input material resources and waste produced related to the total input material resources
energy and water resources	
waste and emissions	Urban and/or special waste sent to landfills compared to the total waste produced
	Urban and/or special waste collected separately related to the total waste produced
	Special waste recovered compared to the total special waste produced
logistics	
product/service	
human resources, assets, policies	Average energy performance index of buildings for civil use of the organization in year n
sustainability	Has the organization developed or is it implementing a circular economy strategy

List of KPIs & Reference for calculation method:

Information on each specific KPI and its calculation method can be found within the UNI/TS 11820 document.

7.3 ANNEX III: EXPERIENCE FEEDBACK FROM PARTNERS PREVIOUS PROJECTS

This Annex reports the KPIs related to sub-section 3.3. Experience feedback from partners previous projects.

SEREINE

Categories	KPIs (units)	Description
Building envelope	Ubat (W/(m².K)	coefficient of surface heat loss of the envelope by transmission defined in the Th-Bat of RT2005 or RT existing global
	Htr (W/K)	coefficient of heat loss by transmission defined in the standard NF EN ISO 13789 : 2017
	Hve (W/K)	coefficient of heat transfer by air renewal, due to air infiltration, defined in standard NF EN ISO 13789: 2017
	HLC (W/K)	heat loss coefficient of the overall envelope (transmission + air infiltration losses) HLC = Htr + Hve

Reference for calculation method: SEREINE Project, « Protocole de mise en œuvre de la mesure de la performance énergétique intrinsèque de l'enveloppe des maisons individuelles », October 2021

SmartEnCity

Categories	KPIs (units)	Description
Energy protocol	Energy demand kWh/m²a	Energy that the building requires to meet its needs/uses (i.e. heating, DHW, cooling, electricity…)
	Delivered energy (for buildings) kWh/m²a	Delivered energy for heating, cooling, ventilation, domestic hot water, lighting or to produce electricity (EN 15603:2008). User-dependent electricity consumer (computer, refrigerator etc.) are not considered.
	Primary energy (for buildings) kWh/m²a	The annual amount of primary energy (net delivered primary energy) is calculated as the difference between the weighed delivered energy, summed over all energy carriers and weighed exported energy summed over all energy carriers (EN 15603:2008).
	Delivered energy (for energy supply units) kWhin/kWhout	The delivered energy of a large-scale or building-integrated energy supply unit corresponds to the energy entering the energy supply unit (e.g. energy content of light oil, electricity, district heat). The total delivered energy is related to the energy output of the energy supply unit (e.g. electricity, heat, cold).
	Primary energy (for energy supply units) kWhin/kWhout	This is the sum of delivered energies converted into primary energy including the losses of the whole energy chain.
	CO_2 equivalent (for buildings) t CO_2/ m²a	The CO_2 emissions of a building correspond to the emissions that are caused by different areas of application (i.e. space heating, space cooling, domestic water heating, electrical appliances).
	CO_2 equivalent (for energy supply units) t CO_2/ m²a	The CO_2 emissions of a large-scale or building-integrated energy supply unit correspond to the emissions that are caused by the energy output.
	Density of energy demand kWh/m²a	The indicator is defined as ratio of final energy demand (for heating or cooling) of a cohesive set of buildings and a simple figure representing the effort that a district heating or cooling network operator would have

Categories	KPIs (units)	Description
		in order to supply these buildings.
	Peak load and load profile of electricity demand kW	The load profile describes the demand characteristics over time, while peak load is what the electricity supply has to be able to cover.
	Peak load and load profile of thermal (heating/cooling) energy demand kW	The peak load and the load profile of the thermal (heat and cold) energy demand require a high temporal resolution. The load profile describes the demand characteristics over time. The thermal energy supply has to be able to cover the peak load. The load profile gives information about the possibilities or potentials of storage as well as supply-side and demand-side management.
	Specific yield W/(m²·K)	The specific yield is the calculated or metered output energy of a supply system related to the size (capacity) of the system. It often is provided as an annual or monthly value, for closer studies a higher resolution is adequate.
	Degree of congruence of calculated annual final energy demand and monitored consumption %	Ratio of the theoretical energy demand of a building or set of buildings (calculated) and the final energy consumption of a building or set of buildings (measured) over a period of time (e.g. year)
	Degree of energetic self-supply %	The degree of energetic self-supply is defined as ratio of locally produced energy and the local consumption over a period of time (year). The indicators are separately determined for thermal energy (heat or cold) and electricity.
	Share of renewable energy %	Total share of renewable energy sources in a complex energy supply system.
	Efficiency %	Evaluation the efficiency of systems (boiler, solar collector, etc.)
	Internal air temperature ºC	This parameter is directly involved in the determination of internal comfort condition but it also allows to investigate (with another parameter as the heat quantity for set point achievement) how much energy is necessary to reach a particular desired condition known as set point. Use both this parameter (before and after an Energy Conservation Measure (ECM) considering the same set point condition) allows to know how much heating energy has been saved thanks to the ECM's interventions.
	Heat quantity for set point achievement kWh	This parameter allows to collect information about the quantity of energy that is needed to reach a particular temperature condition known as set point. Using this data before and after an ECM (considering the same set point condition) allows to know how much heating energy has been saved thanks to the ECM's interventions.
	Internal relative humidity %	This parameter is a percentage ratio between the quantity of vapour included in an air mass and the maximum quantity of vapour that the same air mass could include under the same conditions of temperature and pressure. This data gives information about the level of saturation of the atmospheric & vapour which value, primary for comfort conditions and ambient healthfulness, should be comprehended between 55% - 65%.
	Internal air speed and distribution m/s	Through this parameter it's possible to know the movement of the air inside the internal ambient. The movement of the air contributes to the healthfulness of the internal air quality level but, this same movement, in function of its speed, could also produce changes in individual comfort conditions due to the augment of the convection heat dissipation or to improper air flows.
	Thermal comfort	This indicator represents the level of thermal comfort measured as the

Categories	KPIs (units)	Description
		number of hours that the indoor temperature and relative humidity conditions are within range of values defined. The range of comfort values varies with the seasons (as it depends on the metabolic rate and clothing of the building users) and the climatology of each city (average monthly temperatures (max & min) and average monthly relative humidity).
LCA protocol	Environmental impact	Global warming potential kg CO_2 eq
		Depletion potential of the stratospheric ozone layer kg CFC 11 eq
		Acidification potential of land and water kg SO_2 eq
		Eutrophication potential kg PO_4^{-3} eq
		Formation potential of tropospheric ozone photochemical oxidants kg C_2H_2 eq
		Abiotic resources depletion potential of elements kg Sb eq
		Abiotic resources depletion potential of fossil fuels MJ
	Resources use	Use of renewable primary energy excluding energy resources used as raw material MJ
		Use of renewable primary energy resources used as raw material MJ
		Use of non-renewable primary energy excluding energy resources used as raw material MJ
		Use of non-renewable primary energy resources used as raw material MJ
		Use of secondary material kg
		Use of renewable secondary fuel MJ
		Use of non-renewable secondary fuel MJ
		Net use of fresh water m^3
	Waste categories	Hazardous wastes disposed kg
		Non-hazardous wastes disposed kg
		Radioactive waste disposed kg
	Output flows	Components for re-use kg
		Materials for recycling kg
		Materials for energy recovery (not being waste incineration) kg
		Exported energy MJ

Reference for calculation method:

The KPIs definition and calculation methodology are described on the guides provided in reports D7.2 (KPIs definition), D7.3 (SmartEnCity evaluation protocols), D7.4 (city impact procedure) and D7.9 (data collection approach).

https://smartencity.eu/media/smartencity_d7_2_kpis_definition_v1.0.pdf
https://smartencity.eu/media/smartencity_d7.3_smartencity_evaluation_protocols_v1.0.pdf
https://smartencity.eu/media/smartencity_d7.4_city_impact_procedure_v1.0_1.pdf
https://smartencity.eu/media/smartencity_d7.9_data_collection_approach_v1.0.pdf

REMOURBAN “Regeneration Model for accelerating the smart urban transformation”

Categories	KPIs (units)	Description
Building and district	·Energy demand [kWh/m^2] ·Energy consumption [kWh/m^2] ·Primary energy consumption [kWh/m^2] ·Useful energy ·Renewable energy production [%] ·CO_2 emissions [TonCO_2/m^2] ·Thermal comfort [%] ·Indoor Air Quality comfort [ppm] ·Energy bill [€] ·Investments [€] ·New patents [nº]	This category covers the efficient actions planned in the project aimed at improving energy efficiency in districts as the use of renewable energy sources, etc.
Urban Mobility	·Energy consumption [MWh] ·CO_2 emissions [TonCO_2] ·NOx emissions [kgNO_x] ·HC emissions [kgHC] ·PM emissions [kgPM] ·EV Penetration Rate [%] ·EV Charging Points [nº] ·Total kWh recharged ·Energy bill [€] ·Investment [€] ·New patents [nº]	This category covers the mobility area, as the use of clean vehicles, charging infrastructure, etc.
ICT Integrated Infrastructures	·Smart meters [nº] ·Meteorological sensors [nº] ·Air quality sensors [nº] ·Indoor sensors [nº] ·Web applications and services [nº] ·Visit/Access to web/services [nº] ·Registered users [nº] ·Investment [€] ·New patents [nº]	This category considers two main aspects, the first one related to measures for infrastructures and ICTs and the second related to the use of the ICTs.
Non-technical actions	·Initiatives of public incentives [nº] ·Awareness raising campaigns [nº] ·Channels used for citizen engagement [nº] ·Visits to project information [nº] ·Social media accounts [nº] ·Marketable products [nº] ·Papers for innovative actions [nº]	This category covers actions related to citizen engagement and communication and exploitation strategies, etc.

Reference for calculation method:

- D2.1 Evaluation Framework of Sustainability and Smartness in cities.
- D2.2 Evaluation protocols and indicators.

HOUSEFUL

Categories	KPIs (units)	Description
Core KPIs	·Energy Circularity Indicator [%] ·Life Cycle Energy consumption [kWhPE] ·Materials Circularity Indicator [%] ·Total material input [kg/m^2] ·Critical Raw Materials [Yes/No] ·Quality of reutilization potential [% of R-strategy] ·Material toxicity [Likert] ·Water Circularity Indicator [%] ·Life Cycle water consumption [m^3] ·Social Added Value [%] ·Energy Poverty [%] ·CO_2 emissions reduction [%] ·Global Warming Potential or Carbon footprint [tCO_2eq] ·Life Cycle Costing [€] ·Net present value [€]	The purpose of HOUSEFUL KPIs is to set up a clear and unambiguous circularity measurement framework encompassing the various aspects of the Circular Economy solutions: - End use. - Water use. - Materials consumption. - Social impact. - Environmental impact. - Economic life cycle cost and value.

Reference for calculation method:

- D2.3 – Reference methodologies and KPIs in circular economy analysis
- D5.1 – HOUSEFUL assessment plan

SCIS

Categories	KPIs (units)	Description
Core KPIs	1) General technical performance indicators ·Energy demand and consumption [kWh/m^2] ·Energy savings [%] ·Degree of energetic self-supply by RES [%] ·Greenhouse Gas emissions [$kgCO_2eq/m^2$] ·Primary energy demand and consumption [kWh/m^2] ·Carbon dioxide emission reduction [$tonesCO_2$] ·Total investments [€/m^2] ·Grants [%] ·Total annual costs [€] ·Payback [years] ·Return on Investment (ROI) [%] 2) General environmental performance indicators ·Reliability [nº failures, %] ·Increased system flexibility for energy players [%] ·Reduction of energy cost [%] ·Peak load reduction [%] ·Increased host capacity for RES, electric vehicles and other new loads [%] ·Consumers engagement [nº]	The KPIs are categorized in the following main groups: 1) General technical performance indicators. 2) General environmental performance indicators. 3) General economic performance indicators. 4) General performance indicators for ICT related technologies. 5) General performance indicators for mobility related technologies. Only those most applicable within REHOUSE are included in the list.

Categories	KPIs (units)	Description
Supporting KPIs	· Increase in Local Renewable Energy Generation [%] ·Number of customers that are positive about the project [nº]·	There are also some supporting KPIs Only those most applicable within REHOUSE are included in the list

Reference for calculation method:

Smart Cities Information System – Key Performance Indicators Guide v2

RINNO PROJECT

Categories	KPIs (units)	Description
Economics	Cost savings in design (€, %)	This KPI provides the economic savings during the design of renovation routes, due to the optimization brought by solutions in the Renovation Repository, Planning & Design Assistant, Retrofitting Manager, Lifecycle Renovation Manager and Renovation Workflow & Transactions Manager.

Reference for calculation method:

RINNO Project « An augmented intelligence-enabled stimulating framework for deep energy renovation delivering occupant-centered innovations», deliverable D1.6 (https://rinno-h2020.eu/rinno-publications/public-deliverables/).

EENSULATE

Categories	KPIs (units)	Description
Building envelope (focus on curtain walls, windows and doors)	U-value (W/m^{2}K)	The amount of heat flow (rate of transfer) of a building element, including the effect of thermal radiation and convection as defined by standards: EN 12631:2012; EN 13947; EN ISO 12567-1; EN ISO 10077 1-2
	Radiation properties – Solar factor G (%)	Solar factor or total solar energy transmittance resulting by the amount of Direct Energy Transmission and Internal Radiated Energy, as defined by standard: EN410
	Acoustic performance – Rw (db)	Weighted sound reduction index, as defined by standards about building elements acoustic insulation: EN ISO 10140-2 ; EN ISO 140-3 ; EN ISO 717-1; UNI EN ISO 10848

Reference for calculation method:

EENSULATE project, «D1.1 - Requirements and drivers of EENSULATE module», December 2016

P2ENDURE

Categories	KPIs (units)	Description
Building energy consumption	Primary energy consumption (kWh/m^{2}year)	The amount of energy that must be provided by the production and distribution system to cover the amount of foreseen energy provision, as defined by Italian national standard: UNI/TS 11300
Indoor Air Quality	CO_2 (ppm)	The amount of indoor CO_2 concentration according to standard EN 16798
	PM – $PM_{2.5}$, PM_{10} (µg/m^3)	The amount of indoor PM concentration as indicated by Victoria EPA institute (Australia)
Thermal comfort	PMV	Predicted mean vote methodology for comfort measurement and verification as defined standards: ISO 7730 and ISO 7726, with

Categories	KPIs (units)	Description
		benchmark indicated in EN 16789
Acoustic comfort	Indoor and outdoor A-weighted sound pressure level (dB(A))	Standard frequency weighting, A-weighting, through which the sound pressure level is filtered, as defined by EN ISO 16283-3 with benchmark methodology indicated in EN ISO 15251

Reference for calculation method:

P2Endure project, «D3.6 – Validation report of improved indoor environment quality», February 2021; «Deployment of Comfort Eye technology for IEQ monitoring »

MIRRORPANEL

Categories	KPIs (units)	Description
Thermal conductivity	W/mK	Thermal conductivity of the new insulation system was 0.038 W/mK with the frame system include which is a really good results comparing on the conventional materials.

Reference for calculation method:

The reference was firstly measured in laboratory scale samples 500 mm 500 mm. After the finding the best coating and running experiment for determining the optimal distance between foils, a full-scale panel had been done. This full panel were transported to the authorized institute for measuring the properties of building materials such as thermal conductivity. The organization (ÉMI) measured the results given above.

After the building was ready the U value was measured too, and were determined and proved the high efficiency of the new insulation material.

In that project no LCA analysis and no carbon sequestration capacity was determined however this KPIs would have been also a good result.

REEHUB

Categories	KPIs (units)	Description
Energy saving	Number of energy audits done	The energy audit simplified gives the energy solution technology for improving energy saving in apartment and the result can be evaluated trough the EPC
Training	Number of participants in capacity building courses	Capacity building tailored to public administration

Reference for calculation method:

The project has described a simplified energy audit methodology that give the possibility to a professional to have a first idea of possible energy saving solution without using software. The methodology is useful for public administration to understand what is an energy audit and the scope and goals.

MADE GREEN IN ITALY

Categories	KPIs (units)	Description
Climate Change	kg CO_2 eq	Radiative forcing as Global Warming Potential (GWP100)
Ozone Depletion	kg CFC-11 eq	Ozone Depletion Potential (ODP)
Human toxicity, cancer	(CTUh)	Comparative Toxic Unit for humans
Human toxicity, non-cancer	(CTUh)	Comparative Toxic Unit for humans
Particulate matter		Impact on human health
Ionising radiation, human health	[kBq U235 eq]	Human exposure efficiency relative to U235
Photochemical ozone formation, human health	[kg NMVOC eq]	Tropospheric ozone concentration increase
Acidification	(AE) [mol H+ eq]	Accumulated Exceedance
Eutrophication, terrestrial	(AE) [mol N eq]	Accumulated Exceedance
Eutrophication, freshwater	kg P eq	Fraction of nutrients reaching freshwater end compartment (P)
Eutrophication, marine	kg N eq	Fraction of nutrients reaching marine end compartment (N)
Ecotoxicity, freshwater*	(CTUe)	Comparative Toxic Unit for ecosystems
Land use	- Soil quality index22 (pt) - Biotic production [kg biotic production] - Erosion resistance [kg soil] - Mechanical filtration [m^3 water] - Groundwater replenishment [m^3 groundwater]	
Water use	m^3 world eq	User deprivation potential (deprivation-weighted water consumption)
Resource use minerals and metals	kg Sb eq	Abiotic resource depletion (ADP ultimate reserves)

Reference for calculation method:

The MGI scheme is based on the Product Environmental Footprint (PEF) methodology, promoted by the European Commission with the Recommendation 2013/179/EC to harmonize the assessment of the environmental impacts of products. EF impact Category Indicators: https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_guidance_v6.3.pdf

ELIH-MED

Categories	KPIs (units)	Description
Social/user's behaviour	Nr of energy efficiency retrofitting completed	Number of energy efficiency retrofit works completed by period
Resource use	Energy saving	Energy savings realized due to energy efficiency retrofit works
Social/user's behaviour	Nr of technicians trained	Number of technicians trained involved in renovations works and pilot actions
Social/user's	Nr of households	Number of households willing to do energy retrofit works

Categories	KPIs (units)	Description
behaviour	reached	
Social/user's behaviour	Nr of decision makers involved	Number of decision makers involved in energy retrofit process of their buildings

BUILD UP SKILLS

Categories	KPIs (units)	Description
Social/user's behaviour	Nr of people trained	Number of trainees involved in pilot actions/national standards/ qualification schemes
	Hours of training	Number of hours of trainings disposed
Social/user behaviour	Reduction of GHG emissions	Number of interventions for energy efficiency improvement, renewable energy increase and climate altering emissions reduction
	Primary energy saving	Number of interventions for energy efficiency improvement
	Renewable energy	Number of interventions for renewable energy increase
	Cumulative investments	Number of interventions for climate altering emissions reduction and related investments

PADOVA FIT

Categories	KPIs (units)	Description
Social/user behaviour	Number of citizens that required information	Number of citizens asked the information about energy renovation works characterising the awareness and trust of homeowners and tenants towards existing products, services and players on the market
	Number of renovation process activated after the IHRS (Integrated Home Renovation Services) consulting	Number of renovation process started after a specialized consulting service
	Level of satisfaction of services	Degree of satisfaction by renovation works
Economics	Amount of financing and funds used	Part of renovation works cost covered by public administrations, private sector (including ESCOs), local businesses, cooperatives financing institutions, insurance companies

7.4 ANNEX IV: SOCIAL FRAMEWORKS

This Annex reports the KPIs and their categories/sub-categories related to sub-section 3.4.

List of s-LCA subcategories linked with stakeholder categories:

Stakeholder Categories	S-LCA subcategories
WORKERS	1. Freedom of association and collective bargaining 2. Child labour 3. Fair salary 4. Working hours 5. Forced labour 6. Equal opportunities/discrimination 7. Health and safety 8. Social benefits/social security 9. Employment relationship 10. Sexual harassment 11. Smallholders including farmers
LOCAL COMMUNITY	1. Access to material resources 2. Access to immaterial resources 3. Delocalization and migration 4. Cultural heritage 5. Safe and healthy living conditions 6. Respect of indigenous rights 7. Community engagement 8. Local employment 9. Secure living conditions
VALUE-CHAIN	1. Fair competition 2. Promoting social responsibility 3. Supplier relationships 4. Respect of intellectual property rights 5. Wealth distribution
CONSUMERS	1. Health and safety 2. Feedback mechanism 3. Consumer privacy 4. Transparency 5. End-of-life responsibility
SOCIETY	1. Public commitments to sustainability issues 2. Contribution to economic development 3. Prevention and mitigation of armed conflicts 4. Technology development 5. Corruption 6. Ethical treatment of animals 7. Poverty alleviation
CHILDREN	1. Education provided in the local community 2. Health issues for children as consumers 3. Children concerns regarding marketing practices

SOCIAL URBAN FRAMEWORK

ITALIA IN CLASSE A

Due to the nature of the framework, the performance indicators are mainly related to the number of retrofitting initiatives linked to information and training actions through behavioural change actions.

Reference for calculation method:

A method has been developed to measure impacts, reported to EC and approved. Furthermore, an attitudinal survey, carried out in 2019, evaluated the effects of information campaigns: in particular, a representative sample of the Italian adult population was reached, for a total of 3,036 respondents.

DECIWATT

Due to the nature of the framework, the main indicator of the performances is related to the number of on-line requests received by the program, through their website or other alternative channels.

Reference for calculation method:

Information about the DeciWatt program are available at the following website:

https://www.cittametropolitana.mi.it/Deciwatt/index.html

7.5 ANNEX V: CITY AND TERRITORY KPIS

The indicators presented here are an extract of the multi-criteria assessment system and are considered potentially significant for the present study in the urban framework, according to the KPIs categories identified within the REHOUSE project. Table 15 indicates the KPIs at urban scale included in categories Environment and built environment, and Resource use.

The details about KPI description and calculation method used in ITACA protocol at urban scale refer to https://www.itaca.org/documenti/news/Protocollo%20ITACA%20Scala%20urbana_211216.pdf

Table 15. City and territory KPIs in categories Environment and built environment and Resource use

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Environment	Ecological footprint (ha)	A measure of how much area of biologically productive land and water that an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices. The Ecological	Energy consumption (kWh) during direct and indirect land occupation, water consumption (m^3) during direct and	LCA tools Method published by Niels Jungbluth, ESU-services Ltd., Uster Ecological Footprint (EF) = sum of time integrated direct land occupation and indirect land occupation

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
		Footprint is usually measured in global hectares. Because trade is global, an individual or country's Footprint includes land or sea from all over the world. Without further specification, Ecological Footprint generally refers to the Ecological Footprint of consumption.	indirect land occupation	
Environment	Ecotoxicity: kg 1,4-dichlorobenzene equivalent (1,4-DB)	This category indicator refers to the impact on freshwater, marine and land ecosystems, as a result of emissions of toxic substances to air, water and soil. Eco-toxicity Potential (FAETP) is calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon and is expressed as 1,4-dichlorobenzene equivalents/kg emission. The indicator applies at global/continental/ regional and local scale	Data to be extracted from LCA tools	Eco-toxicity Potential (FAETP) is calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon
Environment	Eutrophication, terrestrial: Accumulated Exceedance (mol N eq)	These indicators refer to the eutrophying impact on terrestrial, freshwater and marine ecosystems	Data to be extracted from LCA tools	Consistent Life Cycle Inventory activity; commercial tool for LCA calculation process
Environment	Eutrophication, freshwater: Fraction of nutrients reaching freshwater end compartment (kg P eq)			
Environment	Eutrophication, marine: Fraction of nutrients reaching marine end compartment kg N eq			

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Environment and built environment	Conservation of the built environment	Assess the condition of the built environment to reuse it and reduce the use of new construction material	Percentage of preserved area out of the total (%)	X = A/B * 100 A = total preserved surface (m^2) B = total surface excluding not preservable ones (m^2)
	Soil permeability	Assess the percentage of soil permeability to minimize the interruption and contamination of natural water flows	Percentage of soil permeability out of the total (%)	X = B/A*100 A = Total surface of the analysed area (m^2) B = Total permeable surface (m^2)
	Availability of green spaces	Assess the presence of equipped green spaces to increase their availability for the occupants	Rate of equipped green areas (%)	X = (A/B – 1) * 100 A = ratio between green areas and the number of inhabitants in the analysed area B = city average green urban surface per inhabitant
	Requalification of natural framework - regreening	Assess the permeability percentage to make previously sealed surfaces permeable again	Rate of permeability (%)	X = B/A*100 A = total surface of the analysed area (m^2) B = total permeable surface (m^2)
	Reduction of building pressure	Assess the SAT (total farm saturation) variation to avoid the impermeabilization of already saturated areas	SAT variation	Calculate the percentage of SAT variation during the last 20 years within 1 km around the analysed area
Resource use	Intensity of water treatment	Assess the amount of collected and treated wastewater to maximise their potential use to replace drinking water	Rate of collected and treated wastewater (%)	X = B/A*100 = V_{racc} /V_g*100 V_{racc} = Volume of wastewater collected in the project to be reused (m^3/year) (B) V_g = Volume of grey water annually produced (m^3/year) (A)
	Wastewater management	Assess the amount of wastewater to be treated outside the analysed area to maximise the interruption and contamination of natural water flows	Rate of wastewater to be collected and treated outside the analysed area (%)	X = B/A*100 = V_{conf}f/V_g*100 V_{conf} = Volume of wastewater produced in the analysed area (m^3/year) (B) $V_{g,std}$ = Volume of grey water annually produced (m^3/year)
	Use of local vegetation	Assess the amount of vegetation in an area to protect and increase the biodiversity	Percentage of plants, trees, and bushes out of the total (%)	X = B/A*100 A = total number of tree species catalogued in the area B = number of native tree species in the area

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
	Use of xerophytic plants	Assess the amount of xerophytic plants out of the total to reduce water for green areas irrigation	Percentage of xerophytic plants out of the total (%)	Calculate the number of xerophytic plants in the analysed area, divide it by the total number of plants, then calculate the weighted average

Table 16 indicates the KPIs at urban scale included in categories Comfort conditions, Social/user's behaviour and Economics.

Table 16. City and territory KPIs in categories Comfort conditions, Social/user's behaviour and Economics

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
Comfort conditions	Streets and shaded public spaces - thermal comfort	Assess the shaded surfaces (sidewalk, streets etc.) in the analysed urban area to reduce the heat island effect	Percentage of shaded public spaces and streets in the analysed area (%)	X = A/B*100 A = total shaded public surface and streets in the area (m^2) B = total surface of public spaces and streets (m^2)
	Lighting of pedestrian paths	Assess the percentage of pedestrian areas lighted during night to improve pedestrian safety	Percentage of pedestrian areas lighted during night (%)	X = B/A*100 B = pedestrian area lighted during night (m^2) A = total surface of pedestrian zones in the analysed area (m^2)
	Light pollution	Rate of luminous flux above the horizontal plane to reduce the illuminance of sky during night	Rate of luminous flux above the horizontal plane (%)	X = B/A*100 A = number of lighting devices in the analysed area B = number of lighting devices in the analysed area with Rn=0%
	Air quality monitoring	Assess the density of monitoring stations compared to the average to constantly monitor the air quality	Density of monitoring stations compared to the average (%)	X = (ρa/ρc - 1)*100 ρa = density of monitoring stations in the analysed area ρc = density of monitoring stations in the city
	Intensity of greenhouse gas emissions	Assess the amount of greenhouse gas emissions to reduce the CO_2 emissions per capita	Percentage of greenhouse gas emissions compared to the average (%)	$B = \Sigma i\ (Q_{del} * K_{em})$ Q_{del} = energy provided by the energy source for the winter climatization and production of DHW, based on UNI TS 11300 (kWh) K_{em} = CO_2 emission factor of the energy source used for the winter climatization and DHW

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
				production ($kgCO_2/kWh$)
	Intensity of acidifying emissions	Percentage of acidifying conditions compared to the average to reduce NO_x and SO_2 emissions per capita	Percentage of acidifying conditions compared to the average (%)	B = Σi (Q_{del}*K_{em}) Q_{del} = energy provided by the energy source for the winter climatization and production of DHW, based on UNI TS 11300 (kWh) K_{em} = NO_x and SO_2 emission factor of the energy source used for the winter climatization and DHW production ($kgCO_2/kWh$)
	Intensity of photo-oxidant emissions	Percentage of photo-oxidant emissions compared to the average to reduce CO, NO_2 and NMVOC emissions per capita	Percentage of photo-oxidant emissions compared to the average (%)	B = Σi (Q_{del}*K_{em}) Q_{del} = energy provided by the energy source for the winter climatization and production of DHW, based on UNI TS 11300 (kWh) K_{em} = CO, NO_2 and NMVOC emission factor of the energy source used for the winter climatization and DHW production ($kgCO_2/kWh$)
	Increase the number of trees in roads, squares and car parks	Assess the rate of areas with trees to increase the shading in public areas	Percentage of areas with trees (%)	Calculate the length of roads and surfaces of squares with trees in the analysed area, divide them by the total length of roads and surface of squares respectively, then calculate the average
	Intensification of natural urban ventilation	Assess the air flow passing through the built environment to increase its air flow permeability	Density of built environment articulation (qualitative)	CFD simulations or analysis on the effect that obstacles can have on the air flows, concerning the geometry of the buildings
	Thermal comfort of outdoor areas - Albedo	Assess albedo of outdoor areas to mitigate the effect of heat islands	Albedo of outdoor areas (%)	X= B/A*100 = S_{reif}/S_l*100 S_{reif} = total surfaces of the analysed area that can lower the heat island effect (m^2) S_l = total area of intervention (m^2)
	Road network connectivity	Assess the density of crossroads to increase the number of potential routes	Density of crossroads ($1/m^2$)	X = B/A*100 A = total surface of the analysed area B = number of crossroads in the analysed area
	Proximity of cycle paths and driveways	Assess cycle paths adjacent to driveways out of the total to improve the	Percentage of driveways with cycle paths	X = A/B A = length of driveways with adjacent safe cycle paths (m)

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
		use of bikes	adjacent (%)	B = total length of driveways in the analysed area (m)
	Accessibility to pedestrian paths	Assess the percentage of accessible pedestrian paths to guarantee their accessibility	Percentage of accessible pedestrian paths (%)	X = B/A A = length of pedestrian paths that follow the "Design for All" principles in the analysed area (m) B = total length of pedestrian path in the analysed area
	Trend reduction in population risk exposure	Assess the population density to safeguard the public health	Population density	Calculate the population density (inhab/kmq) in the analysed area
Social/ user behaviour	Number of (public/residential/ tertiary) buildings damaged by extreme weather conditions/events (No.)	The sum of buildings damaged by extreme weather conditions/events.	Municipalities, building owners	∑buildings damaged by extreme weather
	Number of days with public service interruptions (e.g. energy/water supply, health/civil protection/emergency services, waste) (No.)	The sum of days with public service interruptions	Municipalities, building owners	∑days with public service interruptions
	Hours needed to inform population of a risk via an early warning system (hours)	The time (hours) needed to inform population of a risk.	Municipalities	∑Hours needed to inform population of a risk
Economics	Economic accessibility to residential property	Assess the surface economically accessible by people with low income to reduce the barriers to residential property	Surface economically accessible by people with low income (m^2)	X = A/B A = minimum salary of the people with low income B = average price of the houses in the analysed area (€/m^2)
	Accessibility to residential rent	Percentage of annual salary in the lowest quintile allocated to rent	A = Average annual rental value in the area under analysis (€/m^2), B = average annual salary of the lowest quintile of the population (€),	X = A/B
	Employment potential	Assess the percentage of jobs compared to the inhabitants of an area to reduce the urban	Percentage of jobs compared to the inhabitants of an	X = A/B A = number of jobs in the analysed area

Category	KPI Indicator (units)	Description	Associated data points/ technical domains considered for assessment	Assessment method/ calculation formula if available
		commuting	area (%)	B = number of working age inhabitants in the analysed area
	Jobs in energy renovation (#Full-time equivalent)	Direct jobs in energy renovation	Municipalities, building owners	Direct jobs in energy renovation (FTE) in a reporting period = ∑ Labour days (FTE) for energy renovation projects in reporting period.
	Upskilling in energy renovation (# Building professionals/ construction workers)	Number of building professionals and Construction workers who upskill in energy renovation annually, including municipal staff.	Municipalities	Upskilling in energy renovation = ∑ building professionals and construction workers who have upskilled in energy renovation in a reporting period