RINNO PROJECT

Report

Transforming energy efficiency in European building stock through technology-enabled deep energy renovation

Deliverable 1.6: Report on RINNO KPIs (v1)

Work Package 1: RINNO Augmented Intelligence Renovation Framework

CIRCE

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Executive Summary

Deliverable 1.6 "Report on RINNO KPIs (v1)" stablishes a set of indicators, providing straightforward information on which are the most promising renovations routes. Having in mind that KPIs are always tied to a target or an objective, the objective of Deliverable 1.6 is to define a preliminary building renovation KPIs list for the evaluation of RINNO technologies/toolkits performance throughout project evolution from a technical, economic, environmental and social perspective. In addition, the most relevant KPIs to the three main steps in the whole renovation process have been selected accordingly; these steps as depicted in the RINNO architecture are: i) Planning & Design, ii) Retrofitting and iii) Life cycle monitoring.

To develop the first version of this deliverable, the following main activities have been conducted:

- A comprehensive literature review and alignment with other initiatives, existing indicator sets and previous projects in the field: Desk based research of relevant documents on building rehabilitation indicators of other relevant H2020 projects, RINNO partners previous experience and considering the Levels, SCIS, SRI frameworks, among others.
- Analysis of synergies with the stakeholder's requirements and market needs identified in T1.1 and WP3 related to the assessment of the most promising renovation routes.
- Definition of a KPI-based assessment methodology, based on the selection of the most relevant indicators in four categories: technical, economic, environmental and social perspective with a focus on the final project impact evaluation.

RINNO KPIs will be used throughout the project to support the development of the RINNO toolkits and the selection of the optimum renovation scenario (WP3), the tools developed to improve the renovation process (WP4), the setup an IoT-middleware for the management and control of the buildings (WP5) and the evaluation of demonstrators and technologies performance (WP6).

A second version of this Deliverable (*D1.7- Report on RINNO KPIs (final version)*) will contain a re-evaluation of the proposed KPIs during the second year of the project when the pilot sites surveys and definition of use case scenarios are finalized. Thus, more relevant KPIs can also be identified to include social, environmental and financial attributes. Thus, the suitability of this preliminary KPI set will be tested till month 24 of the project where a fine-tuning revision will be performed, resulting in the final version of the KPI framework.

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Abbreviations List

AEC	Architecture Engineering Construction
BEMS	Building Energy Management Systems
BM	Business Model
BRP	Building Renovation Passport
CED	Cumulative Energy Demand
DE	Degree of energy self-supply
DHW	Domestic Hot Water
EC	European Commission
EE	Energy Efficiency
EE	Electrical Energy
EI	Expected Impact
EPBD	Energy Performance of Buildings Directive
GWP	Global Warming Potential
ITS	Installation Time Saved
KPI	Key Performance Indicator
nZEB	nearly Zero Energy Building
PEF	Product Environmental Footprint
PEF	Primary Energy Factor
PES	Primary Energy Savings
RACER	Relevance, Acceptability, Clarity, Easiness, Robustness
RES	Renewable Energy Systems
ROI	Return On Investment
RPDA	RINNO Planning and Design Assistant
SCIS	Smart Cities Information System

SRI	Smart Readiness Indicator
TE	Thermal Energy
VOCs	Volatile Organic Compounds
WP	Work Package

1. Introduction

The present report is a public deliverable (D1.6 - Report on RINNO KPIs (V1)) of the RINNO H2020 funded European project, preliminary version of the D1.7- Report on RINNO KPIs (final version). The present Deliverable stablishes a set of indicators to guide in the renovation route decision, providing straightforward information on which are the most promising renovations options from a technical, economic, environmental and social perspective. In addition, the three main steps in the whole renovation process (as depicted in the RINNO architecture): i.e. Planning & Design, ii) actual Construction and Retrofitting and iii) Monitoring and Services provision; are considered for the selection of the most relevant KPIs for the RINNO project.

1.1 RINNO project

The European Commission estimates renovation rate of 3% annually would be needed to accomplish the Union's Energy Efficiency (EE) and environmental ambitions in a cost-effective manner, but with current renovation rates (0.4-1.2% depending on the country) it will take more than 100 years to renovate all the European Union building stock.

The main objective of RINNO is to help drastically accelerate the rate of deep renovation in energy inefficient buildings around Europe reaching an ambitious 3,5% yearly renovation rate in the long-run. The targeted market of RINNO is analysed from both the supply and the demand side. Based on data from a relevant study, the energy renovation market in the EU28 in 2015 was €109 billion (of which residential buildings had the highest share with 65% ≈ €71 billion) and created 882,900 jobs. The 2030 energy renovation market could increase by almost half of the 2015 market if a 40% energy savings target is adopted. Consequently, it can be safely concluded that RINNO solution will enter a growing market that is further supported in a political and regulatory level.

From the demand side, the renovation potential in EU is extremely high, taking into account four key parameters: **a) The volume of residential buildings that need renovation:** according to data from EU building stock observatory, the EU has a residential floor area of 22.7 billion m^2 (or ≈213.7 millions of permanently occupied residential dwellings) of which 77.4% were built before 1990 and 48.8% before 1970 (latest data from 2014 for EU28 and ODYSSEE-MURE Project). **b) The current low renovation rates:** according to data from ZEBRA2020 data tool the equivalent major renovation rate for EU countries participating in the ZEBRA2020 database ranges from 0.08% to 2.01% whereas a business as usual scenario considers a renovation rate of 1%. **c) The cost of deep renovation is still relatively high:** energy renovation costs range from 200-450 €/m^2 depending on the depth of renovation but great discrepancies are observed from country to country. To reduce the cost of deep renovation, there is a need for tailored renovation kits tailored to the building needs, plug-n-play modular components and systems fully integrated with advanced 3D surveying techniques and innovative materials (all addressed by the solution package of RINNO).

To carry out this ambitious project, major technical and socio-economic factors have to be considered, and as a result these factors will offer a portfolio of:

(a) Innovative technologies (building envelope solutions, RES, hybrid and storage solutions).

(b) Processes (off-site/ on-site industrialization, optimization and facilitation).

(c) Business models (based on crowd-equity/ crowd-lending, collaborative financing, energy performance contracting).

The proposed solution will comprise an augmented intelligence framework by enhancing human intelligence through a '1 + 1 > 2' approach on human-machine interaction and by introducing cognitive building capabilities. This combination will stimulate occupants' engagement and will enable optimum and dynamic renovation planning, design, execution and post-renovation operational support. It will also facilitate dynamic energy, environmental and economic assessment of the buildings aligned with the concept of Building Renovation Passports (BRPs).

Through the revised Energy Performance of Buildings Directive (EPBD), the EC aims to establish long-term and cost-effective renovation strategies in order to provide a long-term, step-by-step renovation roadmap, creating new incentives for building renovation.

All these solutions will be demonstrated during RINNO in four demo-sites around Europe, which are already committed for deep-energy renovation.

1.2 Objectives and scope of Deliverable 1.6

RINNO's holistic approach takes into account the interrelationships between a building, its components and its occupants that are often overlooked by traditional renovation practices. Energy related building renovation presents significant impacts mainly on costs and energy reduction[1,2] and cover wider socioeconomic[3,4] and environmental issues[5,6].

The use of a Key Performance Indicators (KPIs) approach is the most popular and valuable tool regarding the measurement of the level of sustainability of construction projects[7]. A KPI is defined as "a quantifiable measure used to evaluate the success of an organization, employee, etc. in meeting objectives for performance"[8], therefore, the key difference between KPIs and other indicators is that KPIs are always tied to a target or an objective[9].

The objective of Deliverable D1.6 is to define a preliminary building renovation KPIs list for the evaluation of RINNO technologies/toolkits performance throughout project evolution from a technical, economic, environmental and social perspective.

The KPIs selected are also intended to provide a preliminary framework to guide in the renovation route decision, providing straightforward information on which are the most promising renovation options. Therefore, the relevant KPIs to the three main steps in the whole renovation process (as depicted in the RINNO architecture): Planning & Design, Retrofitting and Monitoring; are classified accordingly.

[1] Ferreira M (2015), Benefits from energy related building renovation beyond costs, energy and emissions, 6th Interantional Building Physics Conference, IBPC 2015, Energy Procedia.
[2] K. Angelakoglou, K. Kourtzanidis, P. Giourka, V. Apostolopoulos, N. Nikolopoulos and J. Kantorovitch. From a Comprehensive Pool to a Project-Specific List of Key Performance Indicators for Monitoring he Positive Energy Transition of Smart Cities— An Experience-Based Approach. Smart Cities 2020, 3, 705–735; doi:10.3390/smartcities3030036
[3] Davor Mikulić, et al (2016) The socioeconomic impact of energy saving renovation measures in urban buildings, Economic Research-Ekonomska Istraživanja, 29:1, 1109- 1125,
[4] D. Pramangioulis, K. Atsonios, N. Nikolopoulos, D. Rakopoulos, P. Grammelis and E. Kakaras. A Methodology for Determination and Definition of Key Performance Indicators for Smart Grids Development in Island Energy Systems. Energies 12(2), (2019), 242
[5] Pombo O., et al (2016), Sustainability assessment of energy saving measures: A multicriteria approach for residential buildings retrofitting –case study of the Spanish housing stock
[6] D.-S. Kourkoumpas, G. Benekos, N. Nikolopoulos, S. Karellas, P. Grammelis, E. Kakaras. A review of key environmental and energy performance indicators for the case of renewable energy systems when integrated with storage solutions, Applied Energy, 231, (2018), 380-389
[7] Key Performance Indicators (KPIs) approach in buildings renovation for the sustainability of the built environment: A review. AngelikiKyliliaParis A.FokaidesaPetra AmparoLopez Jimenezb
[8] Oxford Dictionary
[9] Bosch P., Jongeneel S., Rovers V., Neumann H.M., Airaksinen M. and Huovila A., CITYkeys indicators for smart city projects and smart cities. 2017, CITYkeys, H2020, Grant Agreement no: 646440

The suitability of this preliminary KPI set will be tested during the first 24 months of the project and, at month 24, a fine-tuning revision will be performed, resulting in the final version of the KPI framework (Deliverable 1.7).

1.3 Link with other RINNO activities

The selection of KPIs considers the renovation needs and requirements of tenants, AECs and business, assessed by means of a survey conducted within Task 1.1. These requirements are measurable and expressed by the group of KPIs selected in this deliverable.

Besides, it is aligned with Task 1.3, where the existing conditions of the pilots in terms of energy consumption, social analysis, etc. were assessed and will form the baseline for the RINNO improvements evaluation. Figure 1 shows the interactions among tasks in WP1.

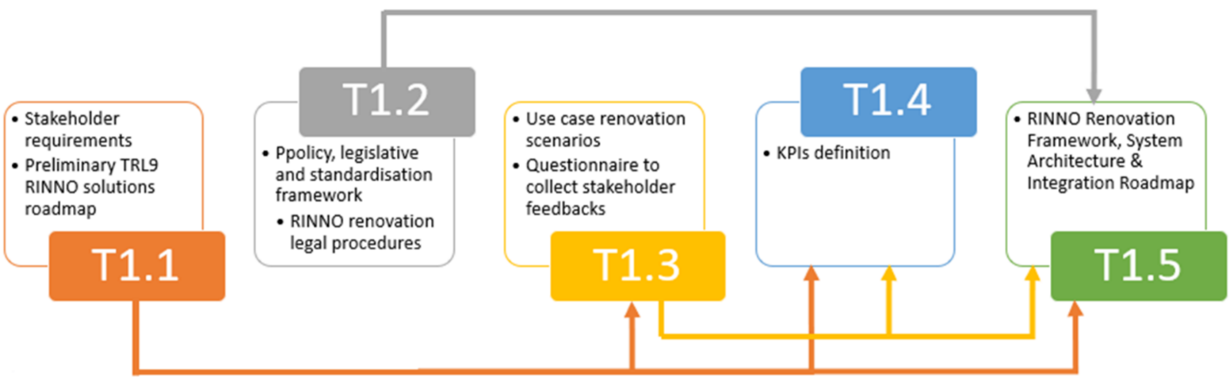

Figure 1. RINNO WP1 interaction.

In addition, RINNO KPIs will be used throughout the project to support the development of the RINNO toolkits and the selection of the optimum renovation scenario (WP3), the tools developed to improve the renovation process (WP4), the setup an IoT-middleware for the management and control of the buildings (WP5) and the evaluation of demonstrators and technologies performance (WP6).

2. Methodological approach

The RINNO KPIs selection is the result of a comprehensive literature review and alignment with other initiatives, existing indicator sets and previous projects in the field. The selection of KPIs was performed considering their ability to provide relevant information on the following dimensions:

1) Technical: focusing on efficiency and other improved design parameters. RINNO project puts together a set of solutions to stimulate large-scale deep energy renovation in residential buildings. In addition, RINNO envisions to further develop the proposed solutions to minimize financial and technical risks, while demonstrating their operational readiness. The majority of the elements included in RINNO's solutions allow a strong degree of automation and interoperability especially when coupled with Building Energy Management Systems (BEMS).

2) Economic: evaluating the cost effectiveness and long-term performance improvement. RINNO can achieve economies of scale if its size is increased. RINNO includes technologies that can be replicated for various building typologies and end-uses. The requirement of significant amount of initial capital can hinder replicability, and for that reason RINNO also supports deep-staged renovation (in accordance with BRP) enabling the systematic renovation in a sensible order and packages. Flexible and novel business models that reduce the need of financing and provide flexible payback mechanisms supports its long-term sustainability.

3) Environmental: assessing the impacts to the environmental footprint, including the life cycle perspective. RINNO solutions are aimed at improving the environmental performance of buildings from many perspectives: reducing the energy consumption, the greenhouse gas emissions along the life cycle of the building, reducing waste and optimizing the use of materials.

4) Social; evaluating the comfort and wellbeing of users. RINNO follows an occupant-centred approach that inherently requires the approval from residents. RINNO will reduce energy bills and improve air quality. Most of the solutions introduced do not require a radical change in the residents' habit since they involve a high level of automatization.

RINNO offers a Suite of Tools that follow a building renovation project throughout the various stages of its lifetime, from the panning/design stage through to the implementation of the renovation measures and the building operation post-retrofit. In the design stage, the RINNO Planning and Design Assistant (RPDA) facilitates the simulation of the generated scenarios and the selection of the optimum one based on its performance on the technical (energy and otherwise), environmental, social as well as economic dimensions. The actual performance of the renovated buildings at the operational stage will be evaluated with the use of the Building Lifecycle Renovation Manager. It should be noted that the latter will communicate with the RPDA to feed in monitored data, thereby supporting staged renovation and the design process with actual data. In addition, the RINNO Retrofitting Manager enables a set of process innovations at the retrofitting stage to facilitate the optimum implementation of the renovation measures in terms of time, cost and occupant disturbance.

Compiled information is used to analyse the replication potential of these methodologies and indicators for the evaluation of RINNO technologies in the building renovation process. The nine different product innovations are clustered in four groups attending to their application field: Insulation improvement, Renewable energy supply, Ventilation and Domestic Hot Water (DHW). In the following table, the main improvements, which should be captured with the KPIs selected, are highlighted:

RINNO renovation solutions	Highlights
Insulation improvement **Bio-based double layer panels (K-FLEX)** **Bio-based pipes and sheets (K-FLEX)** **K-BOX bio-based insulation system (K-FLEX)** **Isocell Cellulose Insulation (EKOLAB)** **Thermochromic glass (GREENSTRUCT)**	- Heating/cooling energy savings - Short installation time - Bio-based content→ fossil-based raw materials avoided - Acoustic insulation - Fire proof/redundant - Recycled materials- Improved comfort and indoor quality - Cost efficient
Renewable energy supply **Climate Cover PV -Roof and -Facade solutions (EKOLAB)** **Building integrated PV glass (GREENSTRUCT)**	- Energy from renewable sources - Cost efficient - Short installation time - Space saving - Recycled materials
Ventilation **MicroVent sustainable Ventilation system (EKOLAB)**	- Short installation time - Cost efficient - Space saving - Improved comfort and indoor quality - Heating/cooling energy savings - Recycled materials
Domestic Hot Water (DHW) **De-centralized DHW preparation (PINK)**	- Space saving - Short installation time - Bio-based content - Energy efficient - Cost-efficient - Energy from RES utilised - Recycled materials

Table 1. Main features highlighted in the RINNO renovation solutions.

The preliminary list of indicators that will be provided in this deliverable will be aligned in a second stage, at M22, with the outcomes of the survey under development in Task 1.1, regarding stakeholders' requirements and markets needs for Building renovation process. In addition, it will consider the simulation scenarios from WP3, the tools and processes developed to improve the renovation process (WP4), the information from the implementation of technologies and combined packages in the renovation demo sites (WP6) and the information of the monitoring during the operational phase (WP5) to achieve project objectives and expected impacts. The objective is that the final list of KPIs can capture the most important requirements and needs, stated by the main stakeholders involved in a renovation process, to help in the decision of which renovation route to follow, as the most promising.

Once the KPIs list is consolidated, the relevancy of the preselected KPIs to assess the specific renovation solutions will be then evaluated. A relevance matrix will be provided and elaborated with the feedback of RINNO solutions providers, to validate the suitability of the final KPIs selected to the specific different solutions. Last, but not least, a final evaluation of indicators according to the RACER criteria will be conducted. RACER criteria include relevance, acceptability, clarity, easiness, robustness.

For the evaluation of KPIs devoted to assessing the RINNO renovation solutions' performance, in terms of technical, economic, environmental and social implications, different sets of data are needed, including a baseline scenario, design data and monitoring data.

A monitoring-based baseline is considered to further compare the performance of the different solutions involved in the Use cases renovation during the Life Cycle Monitoring phase. The objective is to capture the real improvements compared to the current situation, in a straightforward way. Specific energy consumption data of the building and indoor air conditions will need to be metered before the renovation works start as well:

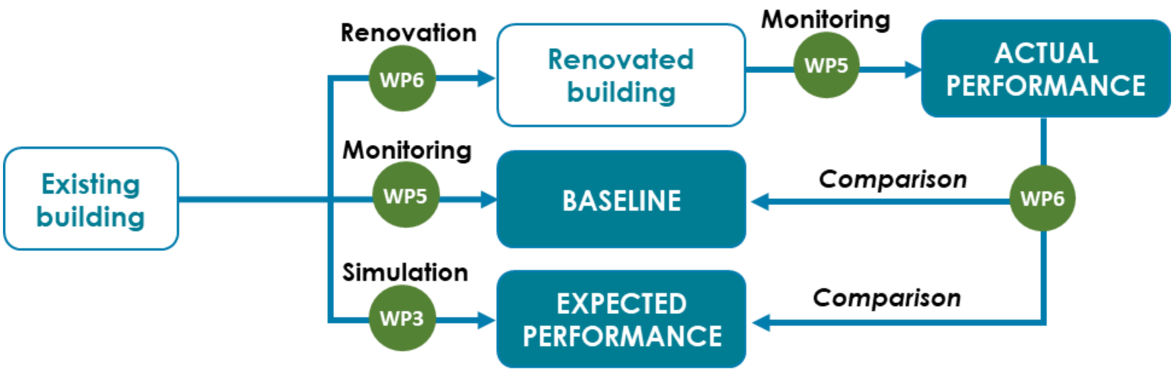

Figure 2. Use cases Monitoring-based evaluation scheme.

On the other hand, the KPIs will also provide guide on which renovation route is more promising during the planning and design stage. In this case, the evaluation scheme will count only performance technical data and simulation information.

Additionally, KPIs will be selected considering, as much as possible, its alignment with the EU expected impacts defined for the call for action "Decarbonisation of the EU building stock: innovative approaches and affordable solutions changing the market for buildings renovation", namely:

- EI 1 "Primary energy savings"
- EI 2 "Investments in sustainable energy triggered by the project"
- EI 3 "High-energy performance in the renovated buildings"
- EI 4 "Measurable cost reduction compared with a typical renovation"
- EI 5 "Reduction of time needed on site for renovation works by 20% compared to current national standard practice"
- EI 6 "Effectiveness and replicability of the solutions to lead to an increased rate of renovation for defined building typologies in several districts/cities/regions"
- EI 7 "Reduction of the greenhouse gases emissions and/or air pollutants triggered

by the project"

The selection of KPIs considers the renovation needs and requirements of stakeholders, assessed by means of a survey analysis and literature review conducted within Task 1.1 and are described in the Deliverable 1.1 "RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (v1)". To capture the preliminary renovation requirements of stakeholders' requirements needs, a comprehensive literature review and alignment with other initiatives and an online questionnaire for data gathering about stakeholder's requirements and needs, barriers and challenges of renovation with targeting all stakeholders in the value chain has been performed in Task 1.1.

3. Building renovation KPIs definition and selection

3.1. Literature research of existing KPIs frameworks

Many initiatives and relevant projects have been recently promoting the adoption of standardized monitoring of the sustainability in buildings and smart cities. RINNO KPIs framework will make use of already consolidated KPIs from the following sources and relevant projects in the field. In addition, to capture all the advances beyond the state-of-the-art of the developed renovation solutions, the RINNO KPIs framework will investigate and include additional KPIs.

- **Smart Cities Information System, SCIS**. Launched with the support of the European Commission, the SCIS is a knowledge platform to exchange data, experience and know-how and to collaborate on the creation of smart cities. Having the overall goal of fostering replication of best practices, a set of comparable KPIs was launched. (Energy demand and consumption, Energy savings, Degree of energy self-supply by RES, Greenhouse Gas Emissions, Primary Energy Demand and Consumption, Carbon dioxide Emission Reduction, Total Investments, total annual costs, payback period, ROI, increased reliability, increased flexibility, peak load reduction, Increased hosting capacity for RES, electric vehicles and other new loads, Consumers engagement)

- **LEVEL(s)** is a framework of core indicators of sustainability for buildings intended to report on and improve the performance of new-build and major renovation projects, developed by the Joint Research Centre, the European Commission's in-house science service. The 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 aspects[10]:

- Environmental performance: Use stage energy performance, life cycle Global Warming potential, bill of quantities, materials and lifespans, construction and demolition waste and materials, design for adaptability and renovation, design for deconstruction, reuse and recycling and use stage water consumption.
- Health and comfort: Indoor air quality, time outside thermal comfort range, lighting and visual comfort and acoustic and protection against noise
- Life cycle cost and value: life cycle costs, value creation and risk exposure
- Potential risks to future performance: Protection of occupier health and thermal comfort, Increased risk of extreme weather events and Increased risk of flood events.

- **Smart Readiness Indicator for Buildings, SRI.** The 2018 revision of the European Energy Performance of Buildings Directive (EPBD) aimed to further promote smart building technologies, in particular through the establishment of a Smart Readiness Indicator (SRI) for buildings. This indicator allow for rating the smart readiness of buildings, i.e. the capability of buildings (or building units) to adapt their operation to the needs of the occupant, also optimizing energy efficiency and overall performance, and to adapt their operation in reaction to signals from the grid (energy flexibility). The smart readiness indicator was intended to raise awareness amongst building owners and occupants of the value behind building automation and electronic monitoring of technical building systems and should give confidence to occupants about the actual savings of those new enhanced

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[10] "Level(s) – A common EU framework of core sustainability indicators for office and residential buildings. User Manual 1: Introduction to the Level(s) common framework". Joint Research Centre October 2020. https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/2020-10/20201013%20New%20Level(s)%20documentation_1%20Introduction_Publication%20v1-0.pdf

functionalities.

- Specific project KPIs from Collaborative EU FP7/H2020 relevant projects e.g. NEED4B, LORE-LCA, OptEEmal, BUILDHEAT, ENRGY IN TIME, ExcEED, HYBUILD, SunHorizon, POCITYF and Collaborative INTERREG SUDOE projects, e.g., ENERBUILCA, URBILCA; Collaborative IEE projects, e.g. ENSLIC, AIDA.

3.2. KPI relevant for solutions selection

A brief overview of the KPIs considered relevant for the assessment of RINNO solutions is provided in this subchapter, classified in the four main dimensions:

Field assessed / Dimension	KPIs	Source / based on
Technical KPIs	- Primary energy savings kWh/(m^2 year) - Design and Installation time saved (hours) - Space saved (m^3) - Degree of energy self-supply by RES (%) - Smart Readiness Indicator	SCIS/LEVELs RINNO RINNO SCIS SRI
Economic KPIs	- Return on Investment (%) - Payback period (years) - Life Cycle cost savings (€) - Cost savings in design (€, %) - Reduction of cost overruns (€, %) - Reduction in construction cost (€, %) - Savings in material cost (€, %)	SCIS SCIS LEVELs RINNO RINNO RINNO RINNO
Environmental KPIs	- Environmental Life cycle GWP savings (kg CO_2eq/(m^2year)) - Embodied Energy savings (kWh/(m^2year)) - Water footprint (l/(m^2year)) - Use of bio-based materials (kg, %) - Use recyclable materials (kg, %) - Use of recycled materials (kg, %) - Waste reduction (kg) - Material use avoided (kg,%)	LEVELs RINNO RINNO RINNO RINNO RINNO RINNO RINNO
Social KPIs	- Time outside Indoor air quality range (hours) - Time outside thermal comfort range (hours) - Time reduction on-site (hours)	LEVELs LEVELs

Field assessed / Dimension	KPIs	Source / based on
		RINNO

** m^2 refers to useful area*

Table 2. RINNO KPIs preliminary list, dimension and source.

The reasoning behind each KPI preselected is provided below:

- **Primary energy yearly savings** (kWh/(m^2·year)). Since RINNO is looking towards nZEB and even positive energy buildings, it aims at maximizing energy performance by decreasing energy consumption and integrating cleaner energy sources, offering high-performance building envelope solutions coupled with RES harvesting, storage and multi-functional hybrid retrofitting solutions. This indicator gathers the result of all the energy performance improvements and its calculation will be easily tracked thanks to the tailored monitoring system to be installed or the simulations to be performed.

This KPI is directly related to the expected impact number 1: "Primary energy savings" and captures the results of the expected impact number 3: "High-energy performance in the renovated buildings".

It is considered in the planning and design phase and in the monitoring/operation phase of the renovation process.

- Design and installation time saved (working hours). The retrofitting process currently being applied in most of the cases is invasive and time-consuming and, as a result, the final cost of a retrofitting project is usually high. Reduction in installation time is a direct result of the use of the RINNO collaborative environment with new tools for the automation and optimization of the data flow during the renovation cycle, reducing inefficacies, errors and duplication of tasks; and the use of prefabricated "plug and play" renovation components, which considerably reduce the construction period. In addition, time savings during design phase can be obtained due to innovative processes, e.g., use of cobots/robots, amount of work conducted offsite, optimized logistics, etc.

This KPI contributes to the expected impact 5: "Reduction of time needed on site for renovation works by 20% compared to current national standard practice".

It is relevant in the construction/installation stage of the renovation process.

- Space saved (m^3/reference unit). RINNO solutions also offer an advantage in terms of space needed in the building, being less invasive solutions and therefore with less impact to the tenants, in comparison to reference/benchmarking alternative solutions. This is considered also an important benefit to consider in the pursuit of higher renovation rates and to increase the roll-out potential of the solutions.

Therefore, this KPI is related to the expected impact number 6: "Demonstration of the effectiveness and replicability of the proposed solutions to lead to an increased rate of renovation for defined building typologies in several districts/cities/regions".

It is relevant in the planning and design stage of the renovation process.

- Degree of energy self-supply by RES (MWh, %). The energy performance of a renovated building can be strengthened either by increasing the energy efficiency or decreasing energy consumption and/or by integrating cleaner energy sources. The RES penetration on a building level due to RINNO product innovations, namely Climate Cover PV-Roof and Façade solutions, Building Integrated Photovoltaic Glass and RES contribution to

Decentralized DHW, will be evaluated under this KPI.

It contributes to the expected impact number 1: "Primary energy savings" and the expected impact number 3: "High-energy performance in the renovated buildings".

It is relevant in the planning and design phase and in the monitoring/operation phase.

- Smart readiness indicator. This KPI intends to be a common Union scheme for rating the ability of buildings to respond to user needs, to interact with the connected energy networks and to operate more efficiently, providing energy savings. It is intended as well to raise awareness about the benefits of smart technologies and ICT in buildings and motivate consumers to accelerate investments in smart buildings technologies.

Smart readiness is expected to become a cost-effective measure that can effectively help in the creation of healthier and more comfortable buildings with a lower energy use and carbon impact and can also facilitate the integration of renewable energy sources.

It contributes to the expected impact number 2: "Investments in sustainable energy triggered by the project" and the expected impact number 4: "Measurable cost reduction compared with a typical renovation".

It is relevant in the monitoring/operation phase.

- Return on investment (%). Renovation cost is the most important barrier to be addressed. This KPI is considered relevant because it enables the evaluation of the feasibility of an investment and the comparison between different alternatives, which can support the decision on which renovation route is more promising. It takes into account both the total investment of the renovation solution and the potential energy savings obtained. Cost reduction achieved through RINNO along with its payback period are important KPIs, because they can increase the market uptake and acceptance rate of deep renovation solutions like the one introduced in RINNO.

This KPI contributes to the expected impact number 4: "Measurable cost reduction compared with a typical renovation" and expected impact number 2: "Investments in sustainable energy triggered by the project".

It is relevant in the planning and design phase of the renovation process.

- Payback period (years). Payback period provides information of the time it takes to recover (because of energy savings) a given investment. It is a widely used indicator and commonly used as complementary to Return on Investment, as it does not consider the savings that are achieved after the payback year. It is specially used to assess the risk. Investments with a short payback period are considered safer than those with a longer payback period[11]. RINNO includes in its solution repository, technologies with low payback period for building tenants/owners, thus a total aimed payback period of less than 4 years is achievable.

This KPI is related to the expected impact number 4: "Measurable cost reduction compared with a typical renovation" and expected impact number 2: "Investments in sustainable energy triggered by the project".

It is relevant in the planning and design phase of the renovation process.

- Life Cycle Cost savings (€). Life cycle cost analysis (LCC) is a method for assessing the total cost of the different phases (production, construction, use and end of life) of a building. Its primary use is in evaluating different options for achieving a client's objectives, where those alternatives differ not only in their initial costs, but also in their subsequent operational cost. Therefore LCC is an economic analysis tool that allows the comparison of various

[11] SCIS

systems or alternatives by examining the total cost in terms of net present value for a building that is designed, built, operated, maintained, and in case demolished throughout the life cycle. Under this definition, smart technologies and their associated savings can be cash flowed in order to capitalise the value of the savings and reflect this in property valuations and investment decisions[12]. Overall cost reduction in RINNO project is attributed to the reduction of costs during design (ranging from 5-30% per solution), reduction of cost overruns (ranging from 5-60%), reduction in construction costs savings in material cost (ranging from 10-50%), and operational and maintenance costs reduction (ranging from 5-50%). In comparison to a reference scenario (current non-renovated building), this KPI gathers, all in all, the cost reduction produced due the different alternative scenarios during all this project stages.

It contributes to the expected impact number 4: "Measurable cost reduction compared with a typical renovation" and expected impact number 2: "Investments in sustainable energy triggered by the project".

It is deemed relevant in all planning and design, construction/renovation and monitoring/operation renovation stages.

RINNO's ICT-enabled acceleration framework includes solutions, namely solutions in the Renovation Repository, Planning & Design Assistant, Retrofitting Manager, Lifecycle Renovation Manager and Renovation Workflow & Transactions Manager, that optimize decision making and flow management during renovation and acting supportively to product cost reductions. This innovative framework will have measurable impacts in the following cost saving-related KPIs: **Cost savings in design (€, %), Reduction of cost overruns (€, %), Reduction in construction cost (€, %) and Savings in material cost (€, %).**

- Environmental Life cycle GWP savings (tCO_2-eq/(m^2 year). RINNO solutions directly contribute to the reduction of energy demand of buildings, therefore to the decarbonisation and the reduction of global warming potential in buildings. In comparison to a reference scenario (current non-renovated building), this KPI can measure the GWP savings.

It directly contributes to the expected impact number 7: "Reduction of the greenhouse gases emissions and/or air pollutants triggered by the project".

This KPI is relevant in all planning and design, construction/renovation and monitoring/operation renovation stages.

- Embodied energy savings (kWh/(m^2year)). In addition to the higher energy efficiency and the production of RES, RINNO solutions are characterized by the reduced embodied energy (total energy required for the extraction, processing, manufacture and delivery of building materials to the building site). The Cumulative Energy Demand (CED) is used since the seventies as an indicator for energy systems. It states the entire demand is assessed as the primary energy which arises in connection with the production, use and disposal of an economic good (product or service) or which may be respectively attributed to it through cause. The CED distinguishes between non-renewable (fossil and nuclear) and renewable primary energy use (hydraulic, biomass, wind, solar and geothermal). In comparison to a reference scenario (current non-renovated building), this KPI can measure the embodied energy savings due to the energy consumption reduction in the operational phase (in terms of primary energy) and considering the embodied energy of the solutions used in the renovation.

This KPI directly contributes to the expected impact number 7: "Reduction of the greenhouse gases emissions and/or air pollutants triggered by the project".

It is deemed relevant in all planning and design, construction/renovation and

[12] LEVELs. Indicator 6.1 on life cycle costs.

monitoring/operation renovation stages.

- Water footprint (l/(m²year)): Even RINNO solutions have not a direct impact in the operational water consumption of the building after renovation, the indicator selected aggregates all freshwater extractions (from rivers, lakes, soil and wells) including water used for cooling processes but excluding water used in turbines in hydraulic power production, under a life cycle perspective of the building. This means the aggregation of water footprint of all components and the corresponding water extraction due the consumption of resources during building´s operation and end of life. Therefore, this indicator can be used to estimate the water footprint of each renovation scenario and select the optimum one.

It is considered in all planning and design, construction/renovation and monitoring/operation renovation stages.

- Use of bio-based materials (kg, %). The increasing importance of the transition towards more sustainable construction materials is addressed in the project with the use of bio-based materials. Coming from renewable raw materials, instead of fossil resources, the new insulation materials used stands as a more environmentally friendly alternative.

It is relevant in the planning and design stage of the renovation process.

- Use of recyclable and recycled materials (kg, %). The aforementioned increasing importance of the transition towards more sustainable construction materials is addressed as well with the use of recyclable and recycled materials.

It is relevant in the planning and design stage of the renovation process.

- Waste reduction (kg, %). Construction and demolition waste accounts for between 10% to 30% of total waste streams, of which 30-50% is attributed to renovation[13]. This KPI will measure the results of the innovative business models (BMs), aimed at rethinking and redesigning renovation procedures in order to minimize waste streams, promote maximum re-use and recycling. Also, RINNO's plug-n-play solutions reduce waste during installation. Indicatively, bio-based insulation materials and solutions provided by K-FLEX avoid solid waste by 50-70% during installation.

This KPI is relevant in the planning and design and construction/installation stages.

- Material use avoided (kg, %). The RINNO innovative BMs, also promotes novel synergies among business to reduce use of raw materials. For example, bio-based insulation materials and solutions provided by K-FLEX use 10% recycled materials and MicroVent ventilation system by EKOLAB utilizes up to 50% less material in comparison with conventional solutions. This KPI will capture the improvements achieved in terms of resources utilization.

This KPI is relevant in the planning and design and construction/installation stages.

- Time outside indoor air quality range (h/year, %). The indoor air quality impacts on human health and depends on some pollutant levels (e.g. dust, Volatile Organic Compounds (VOCs) etc.) and air conditions (e.g. CO_2 and humidity). New and efficient ventilation systems and better insulation (avoiding increased humidity) have a positive impact on better and healthy supply of air.

This KPI is relevant in the planning and design and monitoring/operation renovation stages.

- Time outside of thermal comfort range (h/year, %). This indicator measures the proportion of the year when building occupiers are comfortable with the thermal conditions inside a building and indirectly also measures the ability of a building to maintain pre-defined thermal comfort conditions that will be improved with RINNO solutions.

[13] Balaras C.A., Droutsa K., Dascalaki E., Hansen K. and Petersen E.H., Environmental Impact Assessment of Residential Buildings, INVESTIMMO Project, FP5-Growth

This KPI is relevant in the monitoring/operation renovation stages.

- Time reduction on-site (hours). Prefabricated solutions developed in the project have a direct impact on the reduction of disturbance of tenants due to renovation works.

This KPI is relevant in the monitoring/operation renovation stages.

All the above-mentioned relation between expected impacts and stages of the renovation process are summarized in the table below.

		Renovation stage:			Contribution to Expected Impact:							
Field assessed / Dimension	KPIs	Planning & Design	Retro-fitting	Monitoring/ Operation	EI 1	EI 2	EI 3	EI 4	EI 5	EI 6	EI 7	Additional impacts
Technical KPIs	- Primary energy savings (kWh/(m^2 year))	■		■	■		■					
	- Design and Installation time saved (hours)		■						■			
	- Space saved (m^3)	■								■		
	- Degree of energy self-supply by RES (%)	■		■	■		■					
	- Smart Readiness Indicator (%)			■		■		■				
Economic KPIs	- Return on Investment (%)	■				■		■				
	- Payback period (years)	■				■		■				
	- Life Cycle cost savings (€)	■	■	■		■		■				
	- Cost savings in design (€, %)	■						■				
	- Reduction of cost overruns (€, %)	■	■	■				■				
	- Reduction in construction costs (€, %)		■					■				
	- Savings in material costs (€, %)		■					■				
Environmental KPIs	- Life cycle GWP savings (kgCO$_2$-eq/(m^{2}year))	■		■							■	
	- Embodied Energy savings (kWh/(m^{2}year))	■									■	
	- Water footprint (l/(m^{2}year))	■										■
	- Use of bio-based materials (kg)	■										■
	- Use recyclable materials (kg, %)	■										■
	- Use recycled materials (kg, %)	■										■
	- Waste reduction (kg, %)	■										■
	- Material use avoided (kg,%)	■										■
Social KPIs	- Time outside Indoor air quality range (hours)			■								■
	- Time outside thermal comfort range (hours)			■								■
	- Time reduction on-site (hours)		■									■

EI 1	"Primary energy savings"
EI 2	"Investments in sustainable energy triggered by the project"
EI 3	"High-energy performance in the renovated buildings"
EI 4	"Measurable cost reduction compared with a typical renovation"
EI 5	"Reduction of time needed on site for renovation works by 20% compared to current national standard practice"
EI 6	"Effectiveness and replicability of the solutions to lead to an increased rate of renovation for defined building typologies in several districts/cities/regions"
EI 7	"Reduction of the greenhouse gases emissions and/or air pollutants triggered by the project"

Table 3. *Relevancy of KPIs to renovation process' stages and Expected Impacts (EI).*

4. RINNO KPIs sheets

4.1. Primary energy savings

Dimension:	
Technical	x
Economic	
Environmental	
Social	

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	x

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	x
Public bodies	
Industrial	

Primary energy savings - PES	
KPI Description	This KPI provides the reduction of the primary energy consumption during use stage in the building to reach the same services after the renovation process, compared to the energy consumption in the reference period. Inside the assessment boundary, the system losses are taken into account explicitly in the conversion factor (PEF) applied to the energy carrier, also referred to as a primary energy factor. PEF are, in most cases, provided in each national calculation method. If not, default factors can be found for example in the reference EN standards series EN 15603 and EN ISO 13790. The scope of the indicator includes the following energy uses: heating, cooling, ventilation and domestic hot water. In a life cycle approach, these uses are referred to as operational energy consumption.
Unit	kWh/(m^2 year); MWh/(m^2 year)
Calculation	$PES = \frac{(TE_0 - TE) \times PEF_T + (EE_0 - EE) \times PEF_E}{A_b}$ PES = Primary energy savings TE_0 = Thermal energy (fuels) consumption before renovation (monitored/simulated*) [kWh/(month); kWh/(year)] TE = Thermal energy consumption/demand (fuels) of renovation route x (monitored/simulated*) [kWh/(month); kWh/(year)] EE_0 = Electrical energy consumption before renovation (monitored/simulated) [kWh/(month); kWh/(year)] EE = Electrical energy consumption/demand of renovation route x (monitored/simulated) [kWh/(month); kWh/(year)]

	PEF_T = Primary energy factor for thermal energy (weighted average based on source/fuel mix in production) PEF_E = Primary energy factor for electrical energy (weighted average based on source/fuel mix in production) A_b = Useful area of the building [m^2] ** Both thermal and electrical energy consumption data can derive from monitored data (for instance in the use cases) or from simulation data (in the selection of renovation routes during planning and design stage)*
Sources of information within RINNO	Data from monitoring system before and after the retrofitting via sensors monitoring the main building systems. Monitoring equipment will be installed on the building systems of the four demo buildings, namely the heating, cooling, ventilation and DHW equipment as well as any energy production and storage equipment in order to measure the energy consumption and production prior to and post renovation.
(References)	SCIS and LEVELs
Contribution to Expected Impacts:	• EI1: "Primary energy savings" • EI3: "High-energy performance in the renovated buildings"

4.2. Design and Installation time saved

Dimension:	
Technical	x
Economic	
Environmental	
Social	

Relevant to:	
Design stage	x
Retrofitting stage	x
Operation/monitoring	

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	x
Public bodies	
Industrial	

Design and Installation time saved - DDITS	
KPI Description	This KPI provides the total amount of design and installation time saved, in comparison to benchmarking or reference alternative solutions.
Unit	Hours
Calculation	$$DITS = \sum S_{ei} \cdot h_{saved}/m^2 + P_{PV} \cdot h_{saved}/kW_p + V_{NF} \cdot h_{saved}/(m^3/h) + C_{DHW} \cdot h_{saved}/(l/d) + P \cdot h_{saved}/m + C \cdot h_{saved}/item + D$$ DITS : Design and Installation time saved (hours) in comparison to the reference alternative solutions S_{ei} : Surface of envelope insulation installed (m^2) h_{saved}/m^2 : Envelope insulation solutions hours saved ratio in comparison to the reference alternative solutions P_{PV} : Peak power of PV systems installed (kWp) h_{saved}/kW_p : PV solutions hours saved ratio in comparison to the reference alternative solutions V_{NF} : MicroVent nominal design flow (m^3/h) $h_{saved}/(m^3/h)$: MicroVent hours saved ratio in comparison to the reference alternative solutions C_{DHW} : Capacity of Decentralized DHW installed (l/d) $h_{saved}/(l/d)$: Decentralized DHW hours saved ratio in comparison to the reference alternative solutions P : length of pipes insulated (m) h_{saved}/m : Pipes insulation hours saved ratio in comparison to the reference alternative solutions C : number of components insulated $h_{saved}/item$: Components insulation hours saved ratio in comparison to the reference alternative solutions D: time savings during design stage due to the innovative processes that can be applied with the use of cobots/robots,

	amount of work conducted offsite, optimized logistics, etc.
Sources of information within RINNO	The time saved due to the innovative processes applied during the construction/installation stage, in comparison to the reference alternative solutions, will be provided per reference design unit installed (m^2, kWp, m^3/h, l/d, m and item) by the relevant partner implementing each process.
(References)	RINNO specific
Contribution to Expected Impacts:	• EI5: "Reduction of time needed on site for renovation works by 20% compared to current national standard practice"

4.3. Space saved

Dimension:	
Technical	x
Economic	
Environmental	
Social	

Relevant to:	
Design stage	x
Retrofitting stage	x
Operation/monitoring	

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	x
Public bodies	
Industrial	

Space saved - SS	
KPI Description	This KPI provides the total amount of installation space saved, in comparison to benchmarking or reference alternative solutions.
Unit	m^3
Calculation	$SS = \sum S_{ei} \cdot SS_{envelope}/m^2 + P_{PV} \cdot SS_{PV}/kW_p + V_{NF} \cdot SS_{MICROVENT}/(m^3/h) + C_{DHW} \cdot SS_{DHW}/(l/d) + P \cdot SS_{PIPES}/m + C \cdot SS_{COMP.}/item$ SS : Installation space saved (hours) S_{ei} : Surface of envelope insulation installed (m^2) $SS_{envelope}/m^2$: Envelope insulation solutions space saved ratio (m^3/m^2) in comparison to a conventional system P_{PV} : Peak power of PV systems installed (kWp) SS_{PV}/kW_p : PV solutions space saved ratio in comparison to a conventional system V_{NF} : MicroVent nominal design flow (m^3/h) $SS_{MICROVENT}/(m^3/h)$: MicroVent space saved ratio in comparison to a conventional system C_{DHW} : Capacity of Decentralized DHW installed (l/d) $SS_{DHW}/(l/d)$: Decentralized DHW space saved ratio in comparison to a conventional system P : length of pipes insulated (m) SS_{PIPES}/m : Pipes insulation space saved ratio in comparison to a conventional system C : number of components insulated $SS_{COMP.}/item$: Components insulation space saved ratio in comparison to a conventional system
Sources of information within RINNO	The space saved, in comparison to the reference alternative solutions, will be provided per reference design unit installed (m^2, kWp, m^3/h, l/d, m and item) by technology providers.

(References)	RINNO specific
Contribution to Expected Impacts:	• EI6: "Effectiveness and replicability of the solutions to lead to an increased rate of renovation for defined building typologies in several districts/cities/regions"

4.4. Degree of energy self-supply by RES

Dimension:	
Technical	x
Economic	
Environmental	
Social	

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	x

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	x
Public bodies	
Industrial	

Degree of energy self-supply – DE	
KPI Description	The degree of energy self-supply by RES is defined as ratio of locally produced energy from RES and the energy consumption over a period of time (e.g. month, year). The Degree of energy self-supply (DE) is separately determined for thermal (heating or cooling) energy and electricity. The quantity of locally produced energy is interpreted as by renewable energy sources (RES) produced energy.
Unit	%
Calculation	$DE_T = \frac{LPE_T}{TE_C} \cdot 100$ $\mathrm{DE_T}$ = Degree of thermal energy self-supply based on RES (%) $\mathrm{LPE_T}$ = Renewably produced thermal energy (kWh/month; kWh/year) $\mathrm{TE_C}$ = Total thermal energy consumption (monitored) (kWh/(month); kWh/(year)) $DE_E = \frac{LPE_E}{EE_C} \cdot 100$ $\mathrm{DE_E}$ = Degree of electricity self-supply based on RES $\mathrm{LPE_E}$ = Renewably produced electricity (kWh/month; kWh/year) $\mathrm{EE_C}$ = Total Electricity consumption (monitored) (kWh/(month); kWh/(year))
Sources of information within RINNO	Data from simulations, during design stage, and from monitoring during operation. At the design stage the output of the energy assessment will include the electrical and thermal energy production and consumption for the renovation scenarios. During the operation of the buildings, the relevant information will be provided by the monitoring equipment that will be installed on the heating, cooling, ventilation and DHW equipment as well as any energy production systems of the buildings.

(References)	SCIS
Contribution to Expected Impacts:	• EI1: "Primary energy savings" • EI3: "High-energy performance in the renovated buildings"

4.5. Smart readiness Indicator

Dimension:	
Technical	x
Economic	
Environmental	
Social	x

Relevant to:	
Design stage	
Retrofitting stage	
Operation/monitoring	x

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	x
Public bodies	
Industrial	

Smart Readiness Indicator– SRI	
KPI Description	The Smart Readiness Indicator is an instrument for rating the smart readiness of building, namely, their ability to respond to user needs, to interact with the connected energy networks and to operate more efficiently, providing energy savings. The SRI evaluates seven impact criteria: energy savings on site, maintenance and fault prediction, comfort, convenience, health and wellbeing, information to occupants and grid flexibility and storage.
Unit	%
Calculation	The smart readiness score of a building is a percentage that expresses how close or far the building is to maximal smart readiness. The proposed SRI methodology builds on the assessment of the smart ready services present in the following nine building domains: heating, cooling, domestic hot water, controlled ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging and monitoring and control. For each ready service, functionality levels and associated impact scores are defined (a higher functionality level reflects a “smarter” implementation of the service and higher score). The domain impact score is based on the individual scores for each of the services that are relevant for this domain. For each impact criterion, an impact score is calculated as a weighted average of 9 domain scores. The total SRI score is based on average of total scores on 7 impact criteria. There are two different SRI assessment types defined: A. Simplified method oriented to residential buildings or small non-residential buildings and based on a simplified quick scan of a limited services list. B. Expert SRI assessment focused on non-residential buildings. It requires an on-site inspection by a qualified

	expert based on a more detailed services list. More information about calculation methodology can be found in topic 5 of the recently published guidelines "Final Report on the technical support to the development of a smart readiness indicator for buildings". Catalogue services for method A can be consulted in Annex C. Catalogue services for method B can be consulted in Annex D.
Sources of information within RINNO	Relevant information to determine the Smart Readiness Indicator will be provided by various sources in RINNO: the demo leaders for providing specific information on the systems installed, technology providers for informing the functionalities of their technologies on the various domains and the Building Monitoring System and the Performance dashboard for reporting monitored data.
(References)	Smart Readiness Indicator (SRI) for buildings
Contribution to Expected Impacts:	• EI2: "Investments in sustainable energy triggered by the project" • EI4: "Measurable cost reduction compared with a typical renovation"

4.6. Return on Investment

Dimension:	
Technical	
Economic	x
Environmental	
Social	

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	x

Relevant to stakeholders:	
Designer	
Contractor	
Building owner	x
Occupants	x
Public bodies	
Industrial	

Return on Investment – ROI	
KPI Description	The return on investment (ROI) is an economic variable that enables the evaluation of the feasibility of an investment or the comparison between different possible investments. This parameter is defined as the ratio between the total savings and the total investment of the project, usually expressed in %.
Unit	%
Calculation	$$ROI_T = \frac{\sum_{t=1}^{T}\left(In_t - TAC_{after_t}\right) - (I_{BR} + I_{ER})}{I_{BR} + I_{ER}}$$ $\mathrm{ROI_T}$: Return on Investment (%) $\mathrm{In_t}$: Savings in year t (€) TAC_{after} : Total annual energy cost of the reference system after renovation (€) I_{BR} : Total investment for all the interventions related to building retrofitting (€) I_{ER}: Total investment for all the interventions related to energy retrofitting (€) T : Duration of the economic analysis period: T=10, 15 and 20 years, depending on the common practice area
Sources of information within RINNO	The ROI, in comparison to the reference alternative solutions, will be available from simulation during design stage as well as from monitoring during operation. The total investment cost for all the interventions related to the building (I_{BR}) and energy retrofitting (I_{ER}) will be provided by the relevant demo leaders. Information on the total annual energy cost will be derived by the monitored energy consumption and relevant assumptions on the cost per energy unit and/or energy bills provided by the occupants/demo leaders. Similarly, any revenues from the power production systems will be determined through the measured energy produced and suitable tariffs and/or from invoices collected from the demo leaders.

(References)	SCIS
Contribution to Expected Impacts:	• EI2: "Investments in sustainable energy triggered by the project" • EI4: "Measurable cost reduction compared with a typical renovation"

4.7. Payback period

Dimension:	
Technical	
Economic	x
Environmental	
Social	

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	x

Relevant to stakeholders:	
Designer	
Contractor	
Building owner	x
Occupants	
Public bodies	
Industrial	

Payback period – EPP	
KPI Description	The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment and the time at which cumulative savings offset the investment. Simple payback takes real (non-discounted) values for future monies. Discounted payback uses present values. Payback in general ignores all costs and savings that occur after payback has been reached, therefore it is usually considered as an additional criterion to assess the investment, especially to assess the risks.
Unit	Years
Calculation	Type A simple (non-discounted values for future money): $$EPP = \frac{EPI_{BR}}{m}$$ EPI_{BR} : Energy-related investment (€) m : can be calculated as average total annual costs (TAC) in use savings (€/year) $$m = TAC_{after} - TAC_{before}$$ Type B discounted: $$EPP = \frac{ln\big(m \cdot (1+i)\big) - ln(EPI_{BR} - EPI_{BR} \cdot (1+i) + m)}{ln(1+i)} - 1$$ Type C discounted with energy price increase rate: $$EPP = \frac{ln\big(m \cdot (1+i)\big) - ln(EPI_{BR}(1+p) - EPI_{BR} \cdot (1+i) + (1+p)m)}{ln(1+i) - ln(1+p)} - 1$$ i (%) = Discount rate p (%) = Energy price increase rate i should be unequal to p
Sources of information within RINNO	The Payback period, in comparison to the reference alternative solutions, will be available from simulation during design stage as well as from monitoring during operation. Information on the total annual energy cost will be derived by the monitored energy consumption and

	relevant assumptions on the cost per energy unit and/or energy bills provided by the occupants/demo leaders. Similarly, any revenues from the power production systems will be determined through the measured energy produced and suitable tariffs and/or from invoices collected from the demo leaders.
(References)	SCIS
Contribution to Expected Impacts:	• EI2: “Investments in sustainable energy triggered by the project” • EI4: “Measurable cost reduction compared with a typical renovation”

4.8. Life Cycle cost savings

Dimension:	
Technical	
Economic	x
Environmental	
Social	

Relevant to:	
Design stage	x
Retrofitting stage	x
Operation/monitoring	x

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	
Public bodies	
Industrial	

Life Cycle Cost savings – LCCs	
KPI Description	The indicator measures all building element costs incurred at each life cycle stage of a renovation project for the reference study period and the intended service life. This KPI reflects the potential for long term performance improvement, inclusive of acquisition, operation, maintenance, refurbishment, disposal and end of life. The reference standard for calculating the life cycle costs of each life cycle stage shall be ISO 15686-5 and EN 16627
Unit	€/(m^2year)
Calculation	$LCC_{s,i} = LCC_0 - LCC_i$ $LCC_{s,i}$: Life Cycle Cost savings due to renovation route *i (€).* LCC_0 : Life Cycle Cost of baseline (building before renovation) *(€).* LCC_i : Life Cycle Cost of renovation route *i (€).*
Sources of information within RINNO	Input from Life Cycle Cost calculated in WP 3.
(References)	LEVELs
Contribution to Expected Impacts:	• EI2: “Investments in sustainable energy triggered by the project” • EI4: “Measurable cost reduction compared with a typical renovation”

4.9. Cost savings in design

Dimension:	
Technical	
Economic	x
Environmental	
Social	

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	
Public bodies	
Industrial	

Cost savings in design – CDS	
KPI Description	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.
Unit	€, %
Calculation	$CDS\ (€) = \sum S_{ei} \cdot DC_{saved}/m^2 + P_{PV} \cdot DC_{saved}/kW_p + V_{NF} \cdot DC_{saved}/(m^3/h) + DC$ $CDS\ (€) = \frac{CDS(€)}{TDC\ (€)}$ S_{ei} : Surface of envelope insulation installed (m^2) DC_{saved}/m^2 : Envelope insulation solutions design costs saved ratio in comparison to the reference alternative solutions (€/m^2) P_{PV} : Peak power of PV systems installed (kWp) DC_{saved}/kWp : PV solutions design costs saved ratio in comparison to the reference alternative solutions (€/kWp) V_{NF} : MicroVent nominal design flow (m^3/h) $DC_{saved}/(m^3/h)$: MicroVent design costs saved ratio in comparison to the reference alternative solutions (€/m^3/h) DC: Costs saved during design stage due to Planning & Design Assistant, Retrofitting Manager, Lifecycle Renovation Manager and Renovation Workflow & Transactions Manager (€) TDC: Theoretical design cost of the renovation route, without RINNO innovations (€)
Sources of information within RINNO	The cost saving in design due to the innovative solutions, in comparison to the reference alternative solutions, will be provided per reference design unit installed (m^2, kWp, m^3/h) by the relevant partner implementing each process.

(References)	RINNO
Contribution to Expected Impacts:	• EI4: "Measurable cost reduction compared with a typical renovation"

4.10. Reduction of cost overruns

Dimension:	
Technical	
Economic	x
Environmental	
Social	

Relevant to:	
Design stage	x
Retrofitting stage	x
Operation/monitoring	

Relevant to stakeholders:	
Designer	
Contractor	x
Building owner	
Occupants	
Public bodies	
Industrial	

Reduction of cost overruns - RCO	
KPI Description	This KPI provides the economic savings due to the reduction of cost overruns resulting from the toolkit developed in the project, including 3D-printing, the use of robots/cobots and improved communication, clear roles and responsibilities, traceability, automated verification and data sharing.
Unit	€, %
Calculation	$$\text{RCO}\ (€) = \sum S_{ei} \cdot CO_{reduction}/m^2 + P_{PV} \cdot CO_{reduction}/kW_p + V_{NF} \cdot CO_{reduction}/(m^3/h) + CO$$ $$\text{RCO}\ (\%) = \frac{RCO(€)}{TCO(€)}$$ S_{ei} : Surface of envelope insulation installed (m^2) $CO_{reduction}/m^2$: Envelope insulation solutions overruns saved ratio in comparison to the reference alternative solutions (€/m^2) P_{PV} : Peak power of PV systems installed (kWp) $CO_{reduction}/kWp$: PV solutions overruns saved ratio in comparison to the reference alternative solutions (€/kWp) V_{NF} : MicroVent nominal design flow (m^3/h) $CO_{reduction}/(m^3/h)$: MicroVent overruns saved ratio in comparison to the reference alternative solutions (€/m^3/h) CO: Reduction of cost overruns due to Planning & Design Assistant, Retrofitting Manager, Lifecycle Renovation Manager (€) TCO: Theoretical overruns costs without RINNO innovations (€)
Sources of information within RINNO	The reduction of cost overruns due to the innovative solutions, in comparison to the reference alternative solutions, will be provided per reference design unit installed (m^2, kWp, m^3/h) by the relevant partner implementing each process.

(References)	RINNO
Contribution to Expected Impacts:	• EI4: "Measurable cost reduction compared with a typical renovation"

4.11. Reduction in construction cost

Dimension:	
Technical	
Economic	x
Environmental	
Social	

Relevant to:	
Design stage	x
Retrofitting stage	x
Operation/monitoring	

Relevant to stakeholders:	
Designer	
Contractor	x
Building owner	
Occupants	
Public bodies	
Industrial	

Reduction in construction cost - RCC	
KPI Description	This KPI provides the economic savings during the renovation stage, due to the optimization brought by certain solutions in the Renovation Repository, Planning & Design Assistant, Retrofitting Manager, Lifecycle Renovation Manager and Renovation Workflow & Transactions Manager.
Unit	€, %
Calculation	$RCC\ (€) = \sum S_{ei} \cdot CC_{saved}/m^2 + P_{PV} \cdot CC_{saved}/kW_p + V_{NF} \cdot CC_{saved}/(m^3/h) + CC$ $RCC\ (\%) = \frac{RCC(€)}{TCC(€)}$ S_{ei} : Surface of envelope insulation installed (m^2) CC_{saved}/m^2 : Envelope insulation solutions construction costs saved ratio in comparison to the reference alternative solutions (€/m^2) P_{PV} : Peak power of PV systems installed (kWp) CC_{saved}/kWp : PV solutions construction costs saved ratio in comparison to the reference alternative solutions (€/kWp) V_{NF} : MicroVent nominal design flow (m^3/h) $CC_{saved}/(m^3/h)$: MicroVent construction costs saved ratio in comparison to the reference alternative solutions (€/m^3/h) CC: Construction costs saved attributed to Planning & Design Assistant, Retrofitting Manager, Lifecycle Renovation Manager (€) TCC: Theoretical construction costs without RINNO innovations (€)
Sources of information within RINNO	The construction cost saving due to the innovative solutions, in comparison to the reference alternative solutions, will be provided per reference design unit installed (m^2, kWp, m^3/h) by the relevant

	partner implementing each process.
(References)	RINNO
Contribution to Expected Impacts:	• EI4: "Measurable cost reduction compared with a typical renovation"

4.12. Savings in material cost

Dimension:	
Technical	
Economic	x
Environmental	
Social	

Relevant to:	
Design stage	x
Retrofitting stage	x
Operation/monitoring	

Relevant to stakeholders:	
Designer	x
Contractor	x
Building owner	x
Occupants	
Public bodies	
Industrial	

Savings in material cost - MCS	
KPI Description	This KPI measures the economic savings due to materials cost avoided, attributed to certain solutions in the Renovation Repository, the utilization of Robots/Cobots and 3D printing in the Retrofitting Manager and the Lifecycle Renovation Manager.
Unit	€, %
Calculation	$MCS\ (€) = \sum S_{ei} \cdot MC_{saved}/m^2 + P_{PV} \cdot MC_{saved}/kW_p + V_{NF} \cdot MC_{saved}/(m^3/h) + MC$ $MCS\ (\%) = \frac{MCS(€)}{TMC(€)}$ S_{ei} : Surface of envelope insulation installed (m^2) MC_{saved}/m^2 : Envelope insulation solutions material costs saved ratio in comparison to the reference alternative solutions (€/m^2) P_{PV} : Peak power of PV systems installed (kWp) MC_{saved}/kWp : PV solutions material costs saved ratio in comparison to the reference alternative solutions (€/kWp) V_{NF} : MicroVent nominal design flow (m^3/h) $MC_{saved}/(m^3/h)$: MicroVent material costs saved ratio in comparison to the reference alternative solutions (€/m^3/h) MC: Material costs saved attributed to Retrofitting Manager, Lifecycle Renovation Manager (€) TMC: Theoretical material costs without RINNO innovations (€)
Sources of information within RINNO	The cost saving in materials due to the innovative solutions, in comparison to the reference alternative solutions, will be provided per reference design unit installed (m^2, kWp, m^3/h) by the relevant partner implementing each process.
(References)	RINNO

Contribution to Expected Impacts:	• EI4: "Measurable cost reduction compared with a typical renovation"

4.13. Environmental Life cycle Global Warming Potential savings

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Design stage	x
Retrofitting stage	x
Operation/monitoring	x

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	
Occupants	x
Public bodies	x
Industrial	

Environmental Life Cycle Global Warming Potential savings- GWP	
KPI Description	This indicator measures the contribution of the greenhouse gas (GHG) emissions associated with a building's life cycle to the earth's global warming. It includes the assessment of directly related emissions to the use of energy in a building and the emissions from indirect result of processes to produce, construct, repair, maintain, renovate and eventually deconstruct a building.
Unit	kg $CO_2eq/(m^2year)$
Calculation	$Life\ cycle\ GWP_{s,i} = Life\ cycle\ GWP_0\text{-}Life\ cycle\ GWP_i$ $Life\ cycle\ GWPi = \sum_i GWP_{act/prod}$ $GWP_{act/prod} = \sum_i (GHG_i * GWP_i)$ $GHG_i = \sum_i activity\ data * emission\ factor_i$ Life cycle $GWP_{s,i}$: Life Cycle GWP savings due to renovation route *i* ((g, kg, t) CO_2 eq). Life cycle GWP_0: Life Cycle GWP of baseline (building before renovation) ((g, kg, t) CO_2 eq). Life cycle GWP_i: Global warming potential of the building due the integration of a renovation route i ((g, kg, t) CO_2 eq) $GWP_{,act/prod}$: Global Warming Potential from a product or activity of the renovation route ((g, kg, t) CO_2 eq) $GWP_{,i}$: Global Warming Potential factor of each GHGi ((g, kg, t) CO_2 eq) $GHG_{,i}$: Greenhouse Gas emission due to a specific activity of the

	renovation route *(g, kg, t).*
Sources of information within RINNO	Input from Life Cycle Assessment calculated in WP 3. Based on information from the technology-providers, and CERTH's post-processing
(References)	LEVELs
Contribution to Expected Impacts:	• EI7: "Reduction of the greenhouse gases emissions and/or air pollutants triggered by the project"

4.14. Embodied Energy savings

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	x
Public bodies	
Industrial	

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	x
Public bodies	
Industrial	

Embodied Energy savings	
KPI Description	This KPI measures the reduction in energy consumption during use phase and embodied energy along the building life cycle, including those associated with the manufacturing of construction materials.
Unit	MJ/(m^{2}year)
Calculation	$CED_{s,i} = CED_0 - CED_i$ $CED_{s,i}$: Cumulative Energy Demand savings due to renovation route *i (MJ).* CED_0: Cumulative Energy Demand of baseline (building before renovation) *(MJ)*. CED_i : Cumulative Energy Demand of renovation route scenario *i (MJ).*
Sources of information within RINNO	Input from Life Cycle Assessment calculated in WP 3. Based on information from the technology-providers, and CERTH's post-processing
(References)	RINNO specific
Contribution to Expected Impacts:	• EI7: "Reduction of the greenhouse gases emissions and/or air pollutants triggered by the project"

4.15. Water footprint

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Design stage	x
Retrofitting stage	x
Operation/monitoring	x

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	x
Public bodies	
Industrial	x

Water footprint – WF	
KPI Description	This KPI measures the water use during use phase and embodied water used along the building life cycle, including the associated with the manufacturing of construction materials due to each renovation route proposed.
Unit	l/(m^{2}year)
Calculation	The calculation can be based on the aggregation of water footprint of all components and the corresponding water extraction due the consumption of resources during building´s operation and end of life. Therefore, this indicator can be used to estimate the water footprint of each renovation scenario and select the optimum one.
Sources of information within RINNO	Input from Life Cycle Assessment calculated in WP 3. Based on information from the technology-providers, and CERTH's post-processing.
(References)	RINNO specific
Contribution to Expected Impacts:	This KPI contributes to additional environmental impacts. In this case, with the more efficient use of water resources.

4.16. Use of bio-based materials

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	
Public bodies	x
Industrial	

Use of bio-based materials – BB	
KPI Description	This KPI measures the amount of construction materials used in the renovation process that are bio-based and therefore come from renewable sources.
Unit	kg, %
Calculation	$BB\,(kg) = \sum BB_i \cdot W_i\,;$ $BB\,(\%) = \frac{BB(kg)}{\sum(W_i)}$ i : technologies implemented in the renovation process BB_i : % of biobased materials in the technology *i*. Wi : Weight of technology solution *i* considered in the renovation process (not considering ancillary materials).
Sources of information within RINNO	Information on the bio-based content of the solutions applied, in comparison to the reference alternative solutions, will be provided per reference design unit installed by the technology providers.
(References)	RINNO specific
Contribution to Expected Impacts:	This KPI contributes to additional environmental impacts. In this case, with the use of alternative and renewable raw materials instead of fossil or other finite mineral resources.

4.17. Use of recyclable materials

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	
Public bodies	x
Industrial	

Use of recyclable materials – RbM	
KPI Description	This KPI measures the amount of construction materials used in the renovation process that are recyclable.
Unit	kg, %
Calculation	$RbM\ (kg) = \sum RbM_i \cdot W_i$; $RbM\ (\%) = \frac{RbM\ (kg)}{\sum(W_i)}$ i : solutions implemented in the renovation process RbM_i : % of recyclable materials in the solution *i*. W_i : weight of solution *i* considered in the renovation process (not considering ancillary materials).
Sources of information within RINNO	Information on the recyclable content of the solutions applied, in comparison to the reference alternative solutions, will be provided per reference design unit installed by the technology providers
(References)	RINNO specific
Contribution to Expected Impacts:	This KPI contributes to additional environmental impacts. In this case, with the more efficient use of material resources.

4.18. Use of recycled materials

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	

Relevant to stakeholders:	
Designer	x
Contractor	
Building owner	x
Occupants	
Public bodies	x
Industrial	

Use of recycled materials – RdM	
KPI Description	This KPI measures the amount of construction materials used in the renovation process that are recycled.
Unit	kg, %
Calculation	$RdM\ (kg) = \sum RdM_i \cdot W_i\ ;$ $RdM\ (\%) = \frac{RdM\ (kg)}{\sum(W_i)}$ i : solutions implemented in the renovation process RdM_i : % of recycled materials in the solution *i*. W_i : weight of solution *i* considered in the renovation process (not considering ancillary materials).
Sources of information within RINNO	Information on the recycled content of the solutions applied, in comparison to the reference alternative solutions, will be provided per reference design unit installed by the technology providers
(References)	RINNO specific
Contribution to Expected Impacts:	This KPI contributes to additional environmental impacts. In this case, with the more efficient use of material resources.

4.19. Waste reduction

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Design stage	
Retrofitting stage	x
Operation/monitoring	

Relevant to stakeholders:	
Designer	
Contractor	x
Building owner	x
Occupants	
Public bodies	x
Industrial	

Waste reduction – WR	
KPI Description	This KPI will measure the results of the innovative business models (BMs), aimed at rethinking and redesigning renovation procedures to minimize waste streams, promote maximum re-use and recycling. Also, waste reduction during RINNO's plug-n-play solutions installation. The calculation is based on the waste produced in comparison to benchmarking or reference alternative solutions, for a given reference unit depending on the technology considered (m^2, kWp, …).
Unit	Kg
Calculation	$WR = \sum(S_{ei} \cdot WR_{ei}/m^2 + P_{PV} \cdot WR_{PV}/kW_p + V_{NF} \cdot WR_{VENT}/(m^3/h) + C_{DHW} \cdot WR_{DHW}/(l/d) + P \cdot WR_{PIPES}/m + C \cdot WR_{COMP}/item$ WR : waste reduction (kg) S_{ei} : Surface of envelope insulation installed (m^2) WR_{ei}/m^2 : Envelope insulation solutions waste reduction ratio in comparison to a conventional system. P_{PV} : Peak power of PV systems installed (kWp) WR_{PV}/kW_p : PV solutions waste reduction ratio in comparison to a conventional system. V_{NF} : MicroVent nominal design flow (m^3/h) $WR_{VENT}/(m^3/h)$: MicroVent waste reduction ratio in comparison to a conventional system. C_{DHW} : Capacity of Decentralized DHW installed (l/d) $WR_{DHW}/(l/d)$: Decentralized DHW waste reduction ratio in comparison to a conventional system. P : length of pipes insulated (m) WR_{PIPES}/m : Pipes insulation waste reduction ratio in comparison to a conventional system.

	C : number of components insulated WR_{COMP}/item : Components insulation waste reduction ratio in comparison to a conventional system.
Sources of information within RINNO	Input from Techno Economic Assessment calculated in WP 3.
(References)	RINNO specific
Contribution to Expected Impacts:	This KPI contributes to additional environmental impacts. In this case with the more efficient use of material resources.

4.20. Material use avoided

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	

Relevant to stakeholders:	
Designer	x
Contractor	x
Building owner	
Occupants	
Public bodies	
Industrial	

Material use avoided – MA	
KPI Description	This KPI measure the results of the innovative business models (BMs) and renovation solutions that utilizes less material in comparison with conventional solutions. The calculation is based on the material used in comparison to benchmarking or reference alternative solutions, for a given reference unit depending on the technology considered (m^2, kWp, …).
Unit	Kg
Calculation	$MA = \sum(S_{ei} \cdot MA_{ei}/m^2 + P_{PV} \cdot MA_{PV}/kW_p + V_{NF} \cdot MA_{VENT}/(m^3/h) + C_{DHW} \cdot MA_{DHW}/(l/d) + P \cdot MA_{PIPES}/m + C \cdot MA_{COMP}/item)$ MA : material use avoided (kg) S_{ei} : Surface of envelope insulation installed (m^2) MA_{ei}/m^2 : Envelope insulation solutions material use avoided ratio in comparison to a conventional system. P_{PV} : Peak power of PV systems installed (kWp) MA_{PV}/kW_p : PV solutions material use avoided ratio in comparison to a conventional system. V_{NF} : MicroVent nominal design flow (m^3/h) $MA_{VENT}/(m^3/h)$: MicroVent material use avoided ratio in comparison to a conventional system. C_{DHW} : Capacity of Decentralized DHW installed (l/d) $MA_{DHW}/(l/d)$: Decentralized DHW material use avoided ratio in comparison to a conventional system. P : length of pipes insulated (m) MA_{PIPES}/m : Pipes insulation material use avoided ratio in comparison to a conventional system. C : number of components insulated $MA_{COMP}/item$: Components insulation material use avoided ratio

	in comparison to a conventional system.
Sources of information within RINNO	The amount of raw materials avoided, in comparison to the reference alternative solutions, will be provided per reference design unit installed by technology providers.
(References)	RINNO specific
Contribution to Expected Impacts:	This KPI contributes to additional environmental impacts. In this case with the more efficient use of material resources.

4.21. Time outside indoor air quality range

Dimension:	
Technical	
Economic	
Environmental	
Social	x

Relevant to:	
Design stage	
Retrofitting stage	
Operation/monitoring	x

Relevant to stakeholders:	
Designer	
Contractor	
Building owner	x
Occupants	x
Public bodies	
Industrial	

Time outside Indoor air quality range- IAQ	
KPI Description	This KPI measures the proportion of the year when any of the three main parameters (identified in EN 15251 and EN 16978) in the provision of a healthy and comfortable indoor air supply to occupants, are not reached: ventilation (rate of air change), CO_2 levels and relative humidity. The joint use of air change rate and the concentration of CO_2, result in a measure of the rate at which stale air is replaced with clean intake air. The rate of air exchange also controls the accumulation of other chemical and biological pollutants. On the other hand, the level of relative humidity is an important influencing factor on the comfort of occupants and to avoid creating conditions for the growth of mould, which can provoke respiratory or allergenic problems.
Unit	h/year, %
Calculation	With ventilation system monitoring, indoor air monitoring and indoor thermal monitoring, it should be possible to measure the number of hours/year in which any of the previous three parameters exceed the reference values. Comparing against the baseline scenario, before the retrofitting, it will be possible to measure the improvement in terms of Indoor air quality.
Sources of information within RINNO	Monitored data before and after the retrofitting from sensors installed in the demo buildings
(References)	LEVELs
Contribution to Expected Impacts:	This KPI contributes to health and wellbeing of tenants.

4.22. Time outside thermal comfort range

Dimension:	
Technical	
Economic	
Environmental	
Social	x

Relevant to:	
Design stage	x
Retrofitting stage	
Operation/monitoring	x

Relevant to stakeholders:	
Designer	
Contractor	
Building owner	x
Occupants	x
Public bodies	
Industrial	

Time outside thermal comfort range - IAQ	
KPI Description	This KPI measures, by proxy, the proportion of the year when building occupiers may feel thermal discomfort because temperatures are out of range of defined maximum and minimum temperatures during heating and cooling seasons. Reference temperatures for winter and summer might vary among Member States.
Unit	h/year, %
Calculation	The calculation can be based on both calculated and measured performance, depending on the stage of the renovation process. During design stage to simulate performance and upon completion to check how the building actually performs based on monitored conditions.
Sources of information within RINNO	Monitored data before and after the retrofitting from sensors installed in the demo buildings.
(References)	LEVELs
Contribution to Expected Impacts:	This KPI contributes to health and wellbeing of tenants.

4.23. Time reduction on-site

Dimension:	
Technical	
Economic	
Environmental	
Social	x

Relevant to:	
Design stage	
Retrofitting stage	x
Operation/monitoring	

Relevant to stakeholders:	
Designer	
Contractor	
Building owner	
Occupants	x
Public bodies	
Industrial	

Time reduction on-site - TR	
KPI Description	This KPI measures the time reduction on-site owed to solutions being pre-fabricated and easier to install than conventional solutions, which is linked to reduction of tenants disturbance.
Unit	hours
Calculation	$TR = \sum S_{ei} \cdot h_{saved}/m^2 + P_{PV} \cdot h_{saved}/kW_p + V_{NF} \cdot h_{saved}/(m^3/h) + $ $+ C_{DHW} \cdot h_{saved}/(l/d) + P \cdot h_{saved}/m + C \cdot h_{saved}/item$ TR : Time reduction on-site (hours) S_{ei} : Surface of envelope insulation installed (m^2) h_{saved}/m^2 : Envelope insulation solutions hours saved ratio in comparison to a conventional system P_{PV} : Peak power of PV systems installed (kWp) h_{saved}/kW_p : PV solutions hours saved ratio in comparison to a conventional system V_{NF} : MicroVent nominal design flow (m^3/h) $h_{saved}/(m^3/h)$: MicroVent hours saved ratio in comparison to a conventional system C_{DHW} : Capacity of Decentralized DHW installed (l/d) $h_{saved}/(l/d)$: Decentralized DHW hours saved ratio in comparison to a conventional system P : length of pipes insulated (m) h_{saved}/m : Pipes insulation hours saved ratio in comparison to a conventional system C : number of components insulated $h_{saved}/item$: Components insulation hours saved ratio in comparison to a conventional system
Sources of information within RINNO	The time saved due to the innovative processes applied during the construction/installation stage will be provided by the

	relevant partner implementing each process.
(References)	RINNO
Contribution to Expected Impacts:	This KPI contributes to health and wellbeing of tenants, reducing disturbance due to the on-site renovation works.

5. Conclusions

The preliminary selection of the RINNO KPIs has been conducted following a methodology in which previous relevant frameworks and related projects have been considered. This selection is intended to provide a straightforward view of the main impacts, with a limited, reduced, number of KPIs that can be easily understandable by most of stakeholders identified in the project.

The preliminary building renovation KPIs list will allow the evaluation of RINNO technologies/toolkits performance from a technical, economic, environmental and social perspective. Also, The KPIs selected will support the selection of the most promising renovation options, when integrated in the RINNO Planning & Design Assistant, the Retrofitting Manager and the Lifecycle Renovation Manager.

The final fine tuning of this preliminary KPI set will be conducted during the first 24 months of the project and, at month 24, the final version of the KPI framework will be provided in deliverable 1.7. In this final validation, the interactions with task 1.1 and 1.3 (ongoing) will be evaluated, along with the suitability of the KPIs proposed in the renovation stages and RINNO architecture. Besides, the final quantification of certain parameters needed in the calculations, specially the ones that refer to the comparison against benchmarking/traditional solutions (in the installation time and space saved calculations, Waste reduction and Material use avoided), will be provided. Finally, the defined KPI are fully aligned with the expected impacts and will be a useful monitoring tool towards achieving the project objectives.

Finally, It should be remarked that some of the selected KPIs will be used as an Input/Output variables in the tools/modules being under development and will support the overall RINNO Architecture during the three main steps in the whole renovation process, i.e., i) Planning & Design, ii) actual Construction and Retrofitting and iii) Monitoring and Services provision.

ABOUT RINNO

RINNO is a four-year EU-funded research project that aspires to deliver greener, bio-based, less energy- intensive from a life cycle perspective and easily applicable building renovation elements and energy systems that will reduce the time and cost required for deep energy renovation, while improving the building energy performance. Its ultimate goal is to develop, validate and demonstrate an operational interface with augmented intelligence and an occupant-centered approach that will streamline and facilitate the whole lifecycle of building renovation.

For more information, please visit **https://rinno-h2020.eu/**

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