RINNO

RINNO PROJECT

Report

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

Deliverable 1.7: Report on RINNO KPIs (vf)

Work Package 1: RINNO Augmented Intelligence Renovation Framework

CIRCE

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Executive Summary

Framed in task 1.4 and built upon the previous Deliverable 1.6, in which a preliminary comprehensive building renovation KPIs list for the evaluation of renovation projects, within and beyond RINNO pilots, Deliverable 1.7 "Report on RINNO KPIs (final version)" establishes the refined set of indicators, providing straightforward information on which are the most promising renovation routes.

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

- Assessment of the relevance of the preliminary KPIs set (Deliverable 1.6) with the RINNO key requirements identified in Task 1.1 (Deliverable 1.1).
- Evaluation of the feasibility of the proposed KPIs for the assessment of objectives/drivers of renovation in the RINNO pilots, analysed in the surveys conducted in task 1.3 (Deliverable 1.4).
- Quality evaluation of preliminary list of KPIs with SMART and RACER criteria.
- Refinement of preliminary list of KPIs based on the previous evaluations, resulting on the selection of the most relevant indicators in five categories: technical, economic, environmental, material and social perspective.

After the process, the final set of KPIs is provided and linked to the RINNO tool in which is calculated and the related project's task and responsible partner.

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Abbreviations List

EE	Energy Efficiency
BRPs	Building Renovation Passports
EC	European Commission
EPBD	Energy Performance of Building Directive
ESCO	Energy Services Company
GWP	Global Warming Potential
IoT	Internet of Things
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCC	Life Cycle Costs
RES	Renewable Energy Sources
TRL	Technology Readiness Level
WP	Work Package

1 Introduction

This report is a public deliverable (Deliverable D1.7 "Report on RINNO KPIs (final version)") of the RINNO H2020 funded European project, developed in the framework of the activities of Task 1.4 "Building Renovation Assessment KPIs".

1.1 RINNO Project

According to the EC an annual renovation rate of 3% 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 to drastically accelerate the rate of deep renovation in energy inefficient buildings around Europe reaching an ambitious 3,5% yearly renovation rate in the long-term. Its ultimate goal is to develop, validate and demonstrate an operational interface with augmented intelligence and an occupant-centred approach that will streamline and facilitate the whole building renovation process.

To carry out these ambitious objectives, major technical and socio-economic factors will be considered within the project, supporting the development of a portfolio of:

(a) Innovative technologies (plug-n-play, modular building envelope solutions, renewable energy sources (RES), hybrid and storage solutions).

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

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

The overall proposed solution will comprise an augmented intelligence framework for deep energy renovation in residential buildings by augmenting human intelligence through a '1 + 1 > 2' approach to 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 at establishing a long-term renovation strategies and support cost-effectiveness in order to provide a long-term, step-by-step renovation roadmap, creating new incentives for building renovation. In line with these objectives, RINNO will demonstrate the above-presented technologies and solutions in four demo-sites around Europe, which are already committed to deep-energy renovation.

1.2 Scope and Objectives of Deliverable 1.7

RINNO's holistic approach considers 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 main scope of this deliverable 1.7 is to elaborate the final list of KPIs for the assessment of different potential renovation scenarios, within and beyond RINNO pilots, that will provide straightforward information on the most promising options. In particular, the KPIs detailed from section 2 to 5, are intended to help in the selection of the best renovation scenario, during planning and design stage, and according to key requirements and objectives of the renovation project, that might differ from one case to another.

Additionally, RINNO project delivers other KPIs relevant to further stages of a renovation project, based on the advance tools and monitoring developed, to assess the retrofitting process improvement, from a safety, quality, cost, schedule, environmental and social perspective, and to assess the final impacts of the renovation works, once performed, from an economic, social and environmental point of view. This deliverable is built upon the preliminary building renovation KPIs produced in deliverable D1.6 "Report on RINNO KPIs (v1)" and delivered at month 6. In this document, a preliminary list of KPIs was provided, aimed at a comprehensive assessment of renovation projects, based on existing initiatives and related projects, RINNO technologies and tools expected impacts, bibliography, etc.

In this final version, the quality of KPIs, their alignment with the stakeholders' Key Requirements in terms of building renovation (task 1.1) and their integration in the tools developed by the project have been analyzed, resulting in the final set of KPIs. Also, the feasibility of the proposed KPIs for the evaluation of objectives/drivers of renovation in the RINNO pilots (task 1.3) has been evaluated.

1.3 Relation to Other Activities

The selection of KPIs considers the preliminary results of renovation needs and requirements of stakeholders, assessed in within Task 1.1 and described in the Deliverable 1.1 "RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (v1)". A comprehensive literature review and alignment with other initiatives and an online questionnaire for data gathering about stakeholder's key requirements and needs, barriers and challenges, targeting all stakeholders in the value chain, was performed in Task 1.1. Most of these requirements are measurable and expressed by the group of KPIs selected in this deliverable. Figure 1 shows the interactions among tasks in WP1.

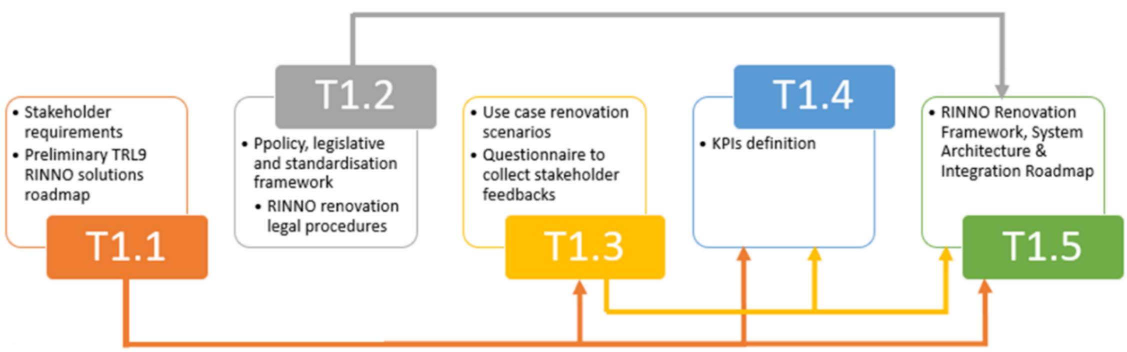

Figure 1 RINNO WP1 interaction

Regarding the link with other WPs, the focus of Deliverable 1.7 is the definition of the KPI-based assessment methodology to:

- To support the selection of the optimum renovation scenario (WP3),
- To drive and communicate improvements of the renovation process (WP4),
- To set up an IoT-middleware for the management and control of the buildings (WP5)
- To evaluate the performance of the pilot demonstrators and technology solutions (WP6).

The list of KPIs provided has been aligned with the outcomes of the survey developed in Task 1.1, regarding stakeholders' key requirements and market needs for the building renovation process. In addition, this final version considers the feedback from 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 outputs of the monitoring during the operational phase (WP5) to achieve project objectives and expected impacts.

2 KPIs relevance to key requirements for the best scenario selection

Key requirements identified and evaluated by relevant stakeholders (designers, Industrial stakeholders -supplier, manufacturer, ESCO, etc.-, building owner and/or resident, contractor and subcontractor and public administrator) within task 1.1 are summarized in 5 categories (more detailed information in deliverable 1.1 table 4-5). One category cannot be prioritized over the others, and a balance is the desired target:

- ✓ Technical aspects: The implementation of solutions that ensure energy savings represent a relevant point for all the stakeholder involved in the study. Also, accuracy of the data gathering of the existing building is a must-have requirement highlighted by the designer's category.
- ✓ Economical aspects: The installation and maintenance costs represent a crucial aspect on the building renovation process with a particular influence on the decision-making process in design/construction phase as well as in the use phase.
- ✓ Environmental aspects: the GHG and other pollutants emission avoidance during the works, as well as during building's use phase, is a common point of focus for interviewed stakeholders. Also, and directly related, the possibility to integrate RES into the building is a relevant and valuable point.
- ✓ Materials: the reduction of waste during the renovation process and an optimized material use are the core elements coming from stakeholders. These aspects are directly related to environmental, economic as well as social benefits, and in this way classified within KPIs framework developed in task 1.4.
- ✓ Social aspects: fundamental aspects to be carefully targeted and managed during the entire renovation work are related to the engagement of owners and residents or occupants. The aspects related to occupants' comfort have to be carefully taken into consideration all along the renovation process to provide comfort during project operations, reducing noise and disturbance, as well as relocation (when possible) and at the end of renovation works, through an optimized management of internal comfort conditions.

Key requirements must be captured, whenever possible, by KPIs that can be measured and are relevant, accepted, credible, easy and robust.

In Table 1 a first analysis in terms of relevance of the preliminary list of KPIs (deliverable 1.6) for key requirements identified (deliverable 1.1) has been performed. An additional category for "materials" has been added, to align the KPIs categories with key requirements. Red means that the key requirement is not considered in any of the proposed KPIs; orange means that the proposed KPI is not considered a key requirement and green means full alignment and relevance of KPI for the given key requirement.

Field assessed	Task 1.4 KPIs	Key requirements identified in task 1.1	
Technical KPIs	Primary energy savings kWh/(m^2year)	Increased energy savings	
	Design and Installation time saved (h)	Installation/time/costs/ workforce saved (reduction of delivery, construction, design and installation time/cost)	
	Space saved (m^3)	Space saving (less invasive solutions)	

Field assessed	Task 1.4 KPIs	Key requirements identified in task 1.1	
	Degree of energy self-supply by RES (%)	Energy from renewable sources	
	Smart Readiness Indicator		
		Accuracy of the data gathering of the existing building	
		Effectiveness and replicability of the solutions and justification of the decision-making process	
Economic KPIs	Return on Investment (%)	Return on Investment	
	Payback period (years)	Payback period	
	Life Cycle cost savings (€)	Life cycle cost savings/reduction	
	Cost savings in design (€, %)	Installation/time/costs/ workforce saved (reduction of delivery, construction, design and installation time/cost)	
	Reduction of cost overruns (€, %)		
	Reduction in construction cost (€, %)		
	Savings in material cost (€, %)		
Environmental KPIs	Life cycle GWP savings (kgCO₂eq/(m²year)	Environmental Life cycle GWP savings/Reduction of the greenhouse gases emissions and/or air pollutants	
	Embodied Energy savings (kWh/(m²year))		
	Water footprint (l/(m²year))		
Materials KPIs	Use of bio-based materials (kg, %)	Use of bio-based materials	
	Use of recyclable materials (kg, %)	Use of recyclable and recycled materials	
	Use of recycled materials (kg, %)		
	Waste reduction (kg)		
	Material use avoided (kg, %)	Reduce use of raw materials (Material use avoided)	
Social KPIs	Time outside Indoor air quality range (h)	Indoor Air quality improvement* Degree of discomfort of the occupants**	
	Time outside thermal comfort range (h)	-Thermal Comfort improvement* -Degree of discomfort of the occupants**	
	Time reduction on-site (h)	Time reduction on site (reduction of visits on site)**	
		Acoustic insulation improvement*	
		No need for the resident to leave the building during the works**	
		Reduction of number of workers on site**	
		Integration of requests from residents**	
		Reduction of accidents/ unforeseen event on site***	

Field assessed	Task 1.4 KPIs	Key requirements identified in task 1.1	
		Easy collaboration with other stakeholders***	
		Easy collaboration with client/supplier***	
		Complaint management improvement***	
		Management of the material on site***	

Table 1 KPIs initial list (task 1.4) and Key Requirements alignment (task 1.1)

* Residents' comfort at the end of the renovation process.

** Residents' comfort during the renovation process.

*** Site quality improvement.

Relevance of proposed KPIs is considered appropriate for all the four categories and main deviations are found for the social KPIs category. The main reason behind is the impossibility of translating the Key requirements into measurable indicators that could be reliably calculated for different renovation routes with the tool under development within RINNO project:

- Acoustic insulation improvement: this key requirement was not considered in the preliminary KPIs list for the selection of the best scenario, but can be later on objectively measured by noise monitoring in decibels., Monitoring of noise is foreseen only in the Polish and French demo-sites, and it can be considered as an indicator for the evaluation of demonstrators, to be calculated within task 6.4.
- No need for the resident to leave the building during the works: this will be addressed by the included KPI quantifying the Disruption Level, calculated by the TEA tool.
- Reduction of number of workers on site: the reduction must be referred to a baseline, which is unknow. However, it will be reshaped into absolute number of "average daily presence of workers on site", which is calculated within TEA tool and can therefore be included in the KPI list.
- Integration of requests from residents: no translation into a measurable indicator is found.
- Reduction of accidents/ unforeseen events on site. the reduction must be referred to a baseline, which is unknow. The quantification in advance of unforeseen events or accidents is found not reasonable.
- Easy collaboration with other stakeholders / with client/supplier: No measurable indicator is found to evaluate easiness.
- Complaint management improvement. No measurable indicator is found to evaluate complaints in advance.
- Management of the material on site: it is not referred to a single and specific feature.

Other two key requirements within the technical field that are not captured by any proposed KPIs are:

- Accuracy of the data gathering of the existing building: no translation into a measurable indicator is found for accuracy of data gathering.

- Effectiveness and replicability of the solutions and justification of the decision-making process: no translation into a measurable indicator is found.

On the other hand, the KPIs Time outside indoor air quality range and Time outside thermal comfort range, calculated in the social-LCA tool, are based on monitored data during operation of buildings, and therefore, they will be very useful to evaluate the impacts of the renovation works and the impacts of the RINNO project (see part 6), but not to select the best renovation scenario.

3 KPIs applicability to Pilot-sites objectives measuring for the selection of the best scenario

The reasons why a renovation project is carried out can be very diverse and vary between different buildings. This hampers to make an assessment based on a single parameter, since the weighting of the objectives/drivers is particular and specific for each case.

In the case of the pilot-sites included in the RINNO project, the objectives and drivers that motivate the renovation projects have been analyzed during task 1.3 and showed the diversity of drivers that can motivate this type of actions. Table 2, Table 3, Table 4 collect the drivers and objectives ranked according to the level of importance rated by the tenants (in bold those with the highest score), together with the related KPIs. Danish demo-site has been excluded from the analysis since it is no longer part of the consortium.

GREEK DEMO	Rating	KPI for best scenario selection
1 Heating cost savings	**5**	**Lifecycle Cost Savings**
2 Cooling cost savings	**5**	**Lifecycle Cost Savings**
3 Minimization of renovation time	**5**	**Duration of works**
4 Residents' comfort	**5**	**Time outside thermal comfort range** (based on monitoring)
5 Better air quality	**5**	**Time outside Indoor air quality range** (based on monitoring)
6 Building life extension	**5**	**X**
7 Carbon footprint	**5**	**Yearly Life Cycle GWP savings**
8 Minimization of renovation costs	4	Life Cycle Cost savings
9 Maintenance cost reduction	4	Life Cycle Cost savings
10 Eco-labelling	4	X
11 Lower noise level	4	X (based on monitoring)
12 Minimization of waste production	4	Waste production
13 Eco-friendliness	4	(Environmental KPIs)
14 Lighting cost savings	3	Life Cycle Cost savings
15 Building aesthetics enhancement	3	X

Table 2 Greek demo site objectives/drivers for renovation and related KPIs.

FRENCH DEMO	Rating	KPI
1 Heating cost savings	**5**	**Lifecycle Cost Savings**
2 Minimization of renovation costs	**5**	**Life Cycle Cost savings**
3 Maintenance cost reduction	**5**	**Life Cycle Cost savings**
4 Residents' comfort	**5**	**Time outside thermal comfort range** (based on monitoring)
5 Building life extension	**5**	**X**
6 Carbon footprint	**5**	**Yearly Life Cycle GWP savings**
7 Eco-friendliness	**5**	**(Environmental KPIs)**
8 Minimization of renovation time	4	Duration of works
9 Building aesthetics enhancement	4	X
10 Minimization of waste production	4	Waste production
11 Eco-labelling	3	X

12 Better air quality	3	Time outside Indoor air quality range (based on monitoring)
13 Lower noise level	3	X (based on monitoring)
14 Cooling cost savings	2	Yearly Primary energy savings
15 Lighting cost savings	2	Yearly Primary energy savings

Table 3 French demo site objectives/drivers for renovation and related KPIs.

POLISH DEMO	Rating	KPI
1 Heating cost savings	**5**	**Lifecycle Cost Savings**
2 Lighting cost savings	**5**	**Lifecycle Cost Savings**
3 Better air quality	**5**	**Time outside Indoor air quality range** (based on monitoring)
4 Minimization of renovation time	4	Duration of works
5 Minimization of renovation costs	4	Life Cycle Cost savings
6 Maintenance cost reduction	4	Life Cycle Cost savings
7 Residents' comfort	4	Time outside thermal comfort range (based on monitoring)
8 Eco-friendliness	4	(Environmental KPIs)
9 Eco-labelling	3	*No KPI exists*
10 Building life extension	3	*No KPI exists*
11 Building aesthetics enhancement	3	*No KPI exists*
12 Carbon footprint	3	Yearly Life Cycle GWP savings
13 Cooling cost savings	2	Yearly Primary energy savings
14 Lower noise level	2	X (based on monitoring)
15 Minimization of waste production	2	Waste production

Table 4 Polish demo site objectives/drivers for renovation and related KPIs.

Both costs savings and air quality are the common top-rated objectives in the three demos. However, the KPI related to the air quality is not calculated in advance as output from simulations, but based on monitored data during the operation stage. In addition, residents' comfort and reduction of costs are among common highly rated objectives. Carbon footprint is the only environmental objective highly rated (only in 2 out of 3 demos).

Building life extension is considered in the three demo sites analysed as a major driver/objective. However, this cannot be translated into a KPI since it is not a performance improvement and it is a common inherent result to all renovation routes. Eco-labelling and aesthetic enhancement are not considered neither within KPIs nor within Key requirements.

For the sake of simplicity, Energy savings (cooling, heating and lighting) as well as costs have been aggregated in just one indicator each, yearly primary energy savings and Life Cycle Costs savings.

4 Evaluation of KPIs quality for the selection of the best scenario

The "RACER" and "SMART" criteria are recommended to be applied to assess the relevance and quality of KPIs used in indicator-based evaluations.

"SMART" criteria requires that the indicators should be Specific, Measurable, Attainable, Relevant, and Time-bound:[10]:

- Specific: Indicator should be sufficiently precise.
  - It should be clear what the indicator expresses (measures);
  - the parameters of the measure should be unambiguous; and
  - it should allow a consistent interpretation (the numbers should not depend on who is producing them and who is interpreting them).
- Measurable: it should be possible to quantify and compare to other data.
  - The data on the parameters defining the indicator should be collectable and available in sufficiently high quality.
  - The indicator should show desirable changes.
  - It should be reliable and a clear measure of results.
- Attainable: it should be possible (realistic) to achieve the target attached to the indicator.
  - The indicator should provide adequate information, with respect to the achievement of the objective.
- Relevant: The indicators must provide appropriate information for the programme/project objectives.
  - It should provide the essence of the desired result/objective
  - It should provide essential information for improvement.
- Time-based: The indicator value should cover a relevant time-frame period.
  - The indicator allows progress to be tracked
  - Indicators must reflect the timing of collection.
  - Necessary data should be available at reasonable cost and effort.

KPIs were evaluated under SMART criteria based on expert judgement with a three-level scoring (green: criterion completely fulfilled; orange: criterion partly fulfilled; red: criterion not fulfilled), supporting the visual presentation of the results. Table 5**Error! Reference source not found.** summarizes the results and main remarks:

	KPI	S (Specific)	M (Measurable)	A (Attainable)	R (Relevant)	T (Time-based)	Comments:
#1	Primary energy savings	Green	Orange	Green	Green	Green	- Timeframe is specified the KPI unit, but it could be also included in the name of the indicator. - yearly data of energy consumption before renovation is needed and might not be always available.
#2	Design and Installation time saved	Orange	Red	Orange	Green	Red	- there are no standard figures or methodology to calculate design and installation time of conventional solutions, running the risk to be based on interested parties stimation, therefore no reliable. - No clear consensus on the selection of which conventional solutions should be used.
#3	Space saved	Orange	Red	Orange	Green	Red	- Same comments as #2.
#4	Degree of energy self-supply by RES	Green	Green	Green	Green	Orange	- timeframe should be better specify.
#5	Smart Readiness Indicator	Red	Red	Orange	Red	Red	- Difficult to interpret, no clear measure of results and time costly. None of the RINNO tools can calculate
#6	Return on Investment	Green	Green	Green	Green	Green	
#7	Payback period	Green	Green	Green	Green	Green	
#8	Life Cycle Cost savings	Green	Green	Green	Green	Orange	- More time-costly than other economic indicators, but less holistic. Performed in VERIFY/LCA database.
#9	Cost savings in design	Orange	Red	Orange	Green	Red	- No standard figures or methodology exists to calculate design costs of conventional solutions, running the risk to be based on interested parties stimation, therefore no reliable. - No clear consensus on the selection of which conventional solutions should be used.
#10	Reduction of cost overruns	Orange	Red	Orange	Green	Red	- No standard figures or methodology exists to calculate conventional cost overruns, running the risk to be based on interested parties stimation, therefore no reliable. - No clear consensus on the selection of which conventional solutions should be used.
#11	Reduction in construction cost	Orange	Red	Orange	Green	Red	- No standard figures or methodology exists to calculate construction costs of conventional solutions, running the risk to be based on interested parties stimation, therefore no reliable. - No clear consensus on the selection of which conventional solutions should be used.
#12	Savings in material cost	Orange	Red	Orange	Green	Red	- There are no standard figures or methodology to calculate materials costs of conventional solutions, running the risk to be based on interested parties stimation, therefore no reliable. - No clear consensus on the selection of which conventional solutions should be used.

	KPI	S (Specific)	M (Measurable)	A (Attainable)	R (Relevant)	T (Time-based)	Comments:
#13	Life Cycle GWP savings						-Timeframe is specified the KPI unit, but it could be also included in the name of the indicator. - The inventory of data needed is sometimes time-costly, but already performed in the project.
#14	Embodied Energy savings						- Same comments as #13. - Embodied energy is not as common as other environmental parameters, therefore could be unclear what the indicator expresses.
#15	Water footprint						- Same comments as #13. - Although water footprint is becoming more popular, it could be unclear that it accounts also for the embodied water in the manufacturing processes as well.
#16	Use of bio-based materials						
#17	Use of recyclable materials						
#18	Use of recycled materials						
#19	Waste reduction						- There are no standard figures or methodology to calculate waste produced during the implementation of a constructive solution, running the risk to be based on interested parties eeestimations. - No clear consensus on the selection of which conventional solutions should be used.
#20	Material use avoided						- There are no standard figures or methodology to calculate materials used during the implementation of a constructive solution, running the risk to be based on interested parties eeestimations. - No clear consensus on the selection of which conventional solutions should be used.
#21	Time outside Indoor air quality range						- Measurable but need of monitoring sensors.
#22	Time outside thermal comfort range						- Measurable but need of monitoring sensors.
#23	Time reduction on-site						- There are no standard figures or methodology to calculate installation time during the implementation of a constructive solution, running the risk to be based on interested parties eeestimations. - No clear consensus on the selection of which conventional solutions should be used.

Table 5 SMART criteria assessment of KPIs

On the other hand, the RACER methodology evaluates indicators according to five criteria: Relevance, Acceptance, credibility, Easiness and Robustness. In more detail:

11 12 13 14

- **Relevant**: is given if the indicator is closely linked to the objectives to be reached.
  - The indicator should be meaningful for the objective quantified.
  - The indicator should be comparable across different cases.
- **Accepted**: Acceptability is given if the indicator is perceived and used by stakeholders and other users.
- **Credible**: it should be accessible to non-experts and easy to interpret.
  - The indicator should follow a clear and transparent methodology.
  - The indicator should be unambiguous.
- **Easy**: it should be feasible to monitor and collect the necessary data at a reasonable cost.
  - The indicator must be easy to calculate
  - Availability of data to calculate indicators
- **Robust**: indicates high data quality and not easily manipulable results.
  - The indicator should be better based on real data than estimations.
  - It should be applicable to numerous (similar but different) cases, delivering reasonable results

RACER criteria were evaluated as well with a three-level scoring (green: criterion completely fulfilled; orange: criterion partly fulfilled; red: criterion not fulfilled), supporting the visual presentation of the results. Table 6 summarizes the results and main remarks:

		R (Relevant)	A (Accepted)	C (Credible)	E (Easy)	R (Robust)	Comments:
#1	Primary energy savings	Green	Green	Green	Green	Green	
#2	Design and Installation time saved	Green	Orange	Red	Green	Red	- No transparent methodology exists and not based on real data
#3	Space saved	Green	Orange	Red	Green	Red	- No transparent methodology exists and not based on real data
#4	Degree of energy self-supply by RES	Green	Green	Green	Green	Green	
#5	Smart Readiness Indicator	Orange	Orange	Red	Red	Orange	- Although with a standard methodology, it is not easy to calculate and interpret. Complex indicator including many heterogeneous things
#6	Return on Investment	Green	Green	Green	Green	Green	
#7	Payback period	Green	Green	Green	Green	Green	
#8	Life Cycle Cost savings	Green	Green	Green	Green	Green	
#9	Cost savings in design	Green	Orange	Red	Green	Red	- No transparent methodology exists and not based on real data
#10	Reduction of cost overruns	Green	Orange	Red	Green	Red	- No transparent methodology exists and not based on real data
#11	Reduction in construction cost	Green	Orange	Red	Green	Red	- No transparent methodology exists and not based on real data
#12	Savings in material cost	Green	Orange	Red	Green	Red	- No transparent methodology exists and not based on real data
#13	Life Cycle GWP	Green	Green	Green	Orange	Green	
#14	Embodied Energy savings	Green	Orange	Green	Orange	Green	- Not as widespread as other environmental indicators
#15	Water footprint	Green	Green	Green	Orange	Green	
#16	Use of bio-based materials	Green	Green	Green	Green	Green	
#17	Use of recyclable materials	Green	Green	Green	Green	Green	
#18	Use of recycled materials	Green	Green	Green	Green	Green	
#19	Waste reduction	Green	Orange	Red	Green	Red	- No transparent methodology exists and not based on real data
#20	Material use avoided	Green	Orange	Red	Green	Red	- No transparent methodology exists and not based on real data
#21	Time outside Indoor air quality range	Green	Green	Green	Orange	Green	- Data only based on monitoring sensors
#22	Time outside thermal comfort range	Green	Green	Green	Orange	Green	- Data only based on monitoring sensors
#23	Time reduction on-site	Green	Orange	Orange	Green	Red	- No transparent methodology exists and not based on real data

Table 6 RACER criteria assessment of initial KPIs list.

Based on the previous analysis, the actions foreseen for those KPIs with one or more not-fulfilled criteria are summarized in the table below:

	KPI	Action:
#1	Primary energy savings	- Update the name to "yearly primary energy savings"
#2	Design and Installation time saved	- Conversion to absolute figures of ONLY installation time →"Duration of works" provided by TEA tool
#3	Space saved	- Remove it from the final KPIs lists. Potential use in the calculation of project impacts (WP6).
#4	Degree of energy self-supply by RES	- Update the name to "yearly degree of self-supply by RES"
#5	Smart Readiness Indicator	- Removed from the final KPIs list. Potential use in the calculation of project impacts (WP6).
#6	Return on Investment	- No action required
#7	Payback period	- No action required
#8	Life Cycle Cost savings	- No action required
#9	Cost savings in design	- All these indicators are aggregated and provided in absolute figures (not reductions) in the LCC.
#10	Reduction of cost overruns	
#11	Reduction in construction cost	
#12	Savings in material cost	
#13	Life Cycle GWP savings	- Update the name to "yearly life cycle GWP savings "
#14	Embodied Energy savings	- Update the name to "yearly Embodied energy savings "
#15	Water footprint	- Update the name to "yearly water footprint savings "
#16	Use of bio-based materials	- It is considered more relevant at technology/product level than at renovation route level. Potential use in the calculation of project impacts (WP6) and in "material passport" (WP7). Source of information: WP2
#17	Use of recyclable materials	- It is considered more relevant at technology/product level than at renovation route level. Potential use in the calculation of project impacts (WP6) and in "material passport" (WP7). Source of information: WP2
#18	Use of recycled materials	- It is considered relevant also at technology/product level, but this information is already available at planning and design stage, from LCA databases and WP2 information. Therefore, it is included as environmental indicator, also given the increasing importance given to the use of recycled materials. Potential additional use in the calculation of project impacts (WP6) and in "material passport" (WP7). Source of information: WP2.
#19	Waste reduction	- Converted to absolute figures of waste produced → provided by TEA tool
#20	Material use avoided	- Remove it from the final KPIs list
#21	Time outside Indoor air quality range	- No action required, but based on monitoring data and so not applicable for the selection of best scenario
#22	Time outside thermal comfort range	No action required, but based on monitoring data and so not applicable for the selection of best scenario
#23	Time reduction on-site	- Conversion to absolute figures of duration of works in days and man-days → TEA tool. Same as #2.

5 Final set of KPIs and relation with RINNO tools for the selection of the best scenario

Considering the outcomes from the analysis of the KPIs' relevance to the identified Key requirements, the quality evaluation of KPIs with the RACER and SMART criteria and their suitability to be used in the selection of the best scenario, several KPIs have been removed from the original list and others have been included or reformulated, resulting in a final list of 11 KPIs. Other KPIs will be calculated and included in task 6.4 for the evaluation of the impacts of the renovation works and improvements achieved in the project, in the context of WP5 and WP6.

In Table 7, the KPIs are linked to the RINNO tools where they are calculated, the responsible partner and the related task. The detailed information about the calculations and sources of information appears in the specific sheets included in this document.

				Responsible partner for calculations:		
Field assessed / Dimension		Final list of KPIs	RINNO TOOLs	Baseline *(Before renovation)*	After renovation	Task
Technical KPIs	1	Yearly Primary energy savings	- INTEMA (final energy/fuel/electricity consumption/energy production) and - VERIFY (Primary energy factor for thermal energy/electricity and total Primary Energy).	CERTH	CERTH/Demo leaders	Task 3.3 Task 6.4
	2	Yearly energy self-supply by RES	- INTEMA for basic energy (electrical/thermal energy production and consumption) and - VERIFY for KPIs calculation	*CERTH*	CERTH/Demo leaders	Task 3.3 Task 6.4
Economic KPIs	3	Return on Investment	- VERIFY for components investment - WP7 business analysis details	*CERTH*	CERTH	Task 3.3 Task 6.4
	4	Payback period	- VERIFY for components investment - WP7 business analysis details	*CERTH*	CERTH	Task 3.3 Task 6.4
	5	Life Cycle Cost savings	VERIFY	CERTH	CERTH	Task 3.3 Task 6.4
Environmental KPIs	6	Yearly Life Cycle GWP savings	VERIFY/LCA database	CIRCE	CIRCE	Task 3.3
	7	Yearly Embodied Energy	VERIFY/LCA database	CIRCE	CIRCE	Task 3.3
	8	Yearly Water footprint	VERIFY/LCA database	CIRCE	CIRCE	Task 3.3
Materials KPIs	9	Waste production	TEA TOOL	*Not applicable*	RINNA + UNN/UNEW	Task 3.3
Social KPIs	10	Duration of works	TEA TOOL	*Not applicable*	RINA + UNN/UNEW	Task 3.3
	11	Disruption Levels	TEA TOOL	*Not applicable*	RINA + UNN/UNEW	Task 3.3

Table 7 Final list of KPIs, responsible partner, related RINNO tool and task.

5.1 Yearly primary energy savings - PES

Dimension:	
Technical	x
Economic	
Environmental	
Social	

Relevant to:	
Planning and design	x
Retrofitting stage	
Monitoring/Operation	x

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

Yearly Primary energy savings - PES	
KPI Description	This KPI provides the reduction of the primary energy consumption in the building during use stage to reach the same services after the renovation process, compared to the energy consumption of the building before renovation, in a yearly basis. Inside the assessment boundary, the system losses are considered 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/year; MWh/year; %
Calculation	$$PES = \frac{(TE_0 - TE) \times PEF_T + (EE_0 - EE) \times PEF_E}{LS}$$ PES = Primary energy savings [kWh/(m^2 year)] 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) LS: Lifespan considered of the renovation project elements (years)

	** 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)* To provide a relative value in percentage: $$PES\ [\%] = \frac{(TE_0 \cdot PEF_T + EE_0 \cdot PEF_E) - (TE \cdot PEF_T + EE \cdot PEF_E)}{(TE_0 \cdot PEF_T + EE_0 \cdot PEF_E)}$$
Sources of information within RINNO	Data from monitoring system before and after the retrofitting, via sensors monitoring of 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 as part of the work conducted in T5.1 – T5.3 (MOTIVIAN and CERTH). The PES will then be calculated based on the actual measured data during the use phase of the building.
Source / based on	SCIS and LEVELs
Contribution to Expected Impacts:	• EI1: “Primary energy savings” • EI3: “High-energy performance in the renovated buildings”

5.2 Yearly energy self-supply by RES - DE

Dimension:	
Technical	x
Economic	
Environmental	
Social	

Relevant to:	
Planning and design	x
Retrofitting stage	
Monitoring/Operation	x

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

Yearly energy self-supply by RES– DE	
KPI Description	The degree of energy self-supply by RES is defined as the 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 by RES (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 produced energy.
Unit	%
Calculation	$$DE = \frac{LPE_T}{TE_C} \cdot 100 + \frac{LPE_E}{EE_C} \cdot 100$$ DE = Yearly energy self-supply by RES $\mathrm{LPE_T}$ = Renewably produced thermal energy [kWh/month; kWh/year] $\mathrm{TE_C}$ = Total thermal energy consumption (monitored) [kWh/(month); kWh/(year)] $\mathrm{LPE_E}$ = 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 (conducted by CERTH's Energy Assessment tool in T3.3.1) 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 in Tasks 5.1 – 5.3 by CERTH and MOTIVIAN.
Source / based on	SCIS
Contribution to Expected Impacts:	• EI1: "Primary energy savings"

	• EI3: "High-energy performance in the renovated buildings"

5.3 Return on investment - ROI

Dimension:	
Technical	
Economic	x
Environmental	
Social	

Relevant to:	
Planning and design	x
Retrofitting stage	
Monitoring/Operation	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 (in this case between different renovation routes). This parameter is defined as the ratio between the total savings and the total investment of the project, usually expressed in %.
Unit	%
Calculation	$$ROI_T = \frac{\sum_{t=1}^{T}\left(In_t - TAC_{after_t}\right) - (I_{BR} + I_{ER})}{I_{BR} + I_{ER}}$$ ROI_T : Return on Investment [%] 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 [years]
Sources of information within RINNO	The ROI, 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 (WP6). Information on the total annual energy cost will be derived by the monitored energy consumption (WP5) 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.

Source / based on	SCIS
Contribution to Expected Impacts:	• EI2: “Investments in sustainable energy triggered by the project” • EI4: “Measurable cost reduction compared with a typical renovation”

5.4 Payback period - EPP

Dimension:	
Technical	
Economic	x
Environmental	
Social	

Relevant to:	
Planning and design	x
Retrofitting stage	
Monitoring/Operation	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: $$EPP = \frac{ln\left(m \cdot (1+i)\right) - ln(EPI_{BR} - EPI_{BR} \cdot (1+i) + m)}{ln(1+i)} - 1$$ Type C discounted with energy price increase rate: $$EPP = \frac{ln\left(m \cdot (1+i)\right) - ln(EPI_{BR}(1+p) - EPI_{BR} \cdot (1+i) + (1+p)m)}{ln(1+i) - ln(1+p)} - 1$$ i (%) = Discount rate p (%) = Energy price increase rate i should be unequal to p
Sources of information within RINNO	The Payback period 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 (WP5 and WP6). 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.
Source / based on	SCIS
Contribution to Expected Impacts:	• EI2: “Investments in sustainable energy triggered by the project” • EI4: “Measurable cost reduction compared with a typical renovation”

5.5 Life Cycle Cost Savings - LCCs

Dimension:	
Technical	
Economic	x
Environmental	
Social	

Relevant to:	
Planning and design	x
Retrofitting stage	x
Monitoring/Operation	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. To procure shorter figures, the total amount of LCC savings ca be divided by lifespan and floor-surface affected by the renovation.
Unit	€
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.
Source / based on	LEVELs
Contribution to Expected Impacts:	• EI2: "Investments in sustainable energy triggered by the project" • EI4: "Measurable cost reduction compared with a typical renovation"

5.6 Yearly Life Cycle Global Warming Potential savings - GWPs

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Planning and design	x
Retrofitting stage	x
Monitoring/Operation	x

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

Yearly Life Cycle Global Warming Potential savings- Life cycle GWPs	
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. To procure shorter figures, the total amount of GWP savings is divided by lifespan.
Unit	kg CO_2eq/year
Calculation	$\textit{Life cycle } GWP_{s,i} = (\textit{Life cycle } GWP_0 - \textit{Life cycle } GWP_i)/LS$ $Life\ cycle\ GWPi = \sum_i GWP_{act/prod}$ $GWP_{act/prod} = \sum_i (GHG_i * GWP_i)$ $GHG_i = \sum_i activity\ data * emission\ factor_i$ 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] LS: Lifespan considered of the renovation project elements (years)

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
Source / based on	LEVELs
Contribution to Expected Impacts:	• EI7: "Reduction of the greenhouse gases emissions and/or air pollutants triggered by the project"

5.7 Yearly embodied energy - EE

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Planning and design	x
Retrofitting stage	
Monitoring/Operation	

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

Yearly Embodied Energy - EE	
KPI Description	This KPI measures the energy consumption during use phase and embodied energy along the building life cycle, including those associated with the manufacturing of construction materials. To procure shorter figures, the total amount of embodied energy savings is divided by lifespan and floor-surface affected by the renovation.
Unit	MJ/year
Calculation	$EE_i = (CED_i)/LS$ EE_i : Yearly embodied Energy due to renovation route *i* [MJ] CED_i : Total embodied energy of all components applied on the building renovation route *i* [MJ] LS: Lifespan considered of the renovation project elements (years)
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
Source / based on	RINNO specific
Contribution to Expected Impacts:	• EI7: "Reduction of the greenhouse gases emissions and/or air pollutants triggered by the project"

5.8 Yearly water footprint - WF

Dimension:	
Technical	
Economic	
Environmental	x
Social	

Relevant to:	
Planning and design	x
Retrofitting stage	x
Monitoring/Operation	x

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

Yearly Water footprint – WF	
KPI Description	This KPI measures the water associated with the construction materials due to each renovation route proposed. To procure shorter figures, the total water footprint is divided by lifespan.
Unit	l/year
Calculation	The calculation can be based on the aggregation of water footprint of all components and their 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.
Source / based on	RINNO specific
Contribution to Expected Impacts:	This KPI contributes to additional environmental impacts. In this case, with the more efficient use of water resources.

5.9 Waste production - WP

Dimension:	
Technical	
Economic	
Environmental	x
Social	x

Relevant to:	
Planning and design	x
Retrofitting stage	
Monitoring/Operation	

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

Waste production – Wp	
KPI Description	This KPI provides a preliminary estimate of the total amount of waste that will be produced during the redevelopment of the building, The result is expressed in volume
Unit	m^3
Calculation	Through the detailed analysis of the activities and their sub-processes considered in the database, it has been possible to associate the amount of waste produced with each of them. The quantities refer to the individual units used for the quantification of the activities. It is thus possible to calculate the quantity of waste produced by category, then combine them by assigning weights to the different types of waste Below is the algorithm used to calculate the indicator. $\sum_{x=1}^{x=m}\sum_{i=1}^{i=n}\frac{Waste_{Packaging}(a_{ix}) \times Coef_{Waste_{Packaging}} + Waste_{Remains}(a_{ix}) \times Coef_{Waste_{Remains}}}{Coef_{Waste_{Packaging}} + Coef_{Waste_{Remains}}}$
Sources of information within RINNO	The information will be available with BIM models of the renovation scenarios to be compared.
Source / based on	RINNO specific
Contribution to Expected Impacts:	This KPI contributes to additional environmental impacts. In this case, allowing the optimal choice in terms of waste produced between different scenarios at an early stage of design.

5.10 Duration of works - DW

Dimension:	
Technical	
Economic	x
Environmental	
Social	x

Relevant to:	
Planning and design	
Retrofitting stage	x
Monitoring/Operation	

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

Duration of works - DW	
KPI Description	This KPI measures the duration of the works for each specific renovation scenario
Unit	N° of days
Calculation	The definition of activities parameterized on quantities available in BIM environment, as well as the definition of rules for the prioritization and sequencing of activities across the different parts of the building, allows the automatic definition of a simplified GANTT in the very early stages of design and, consequently, the estimation of the duration of the works.
Sources of information within RINNO	BIM of existing building and renovation scenarios
Source / based on	RINNO specific
Contribution to Expected Impacts:	This KPI contributes to health and wellbeing of tenants. It allows each inhabitant, at a very early stage in the planning process, to know the duration of the works that may affect their specific apartment and to take the necessary remediation actions in advance.

5.11 Disruption Levels -DL

Dimension:	
Technical	
Economic	x
Environmental	
Social	x

Relevant to:	
Planning and design	x
Retrofitting stage	x
Monitoring/Operation	

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

Average daily presence of workers on site - WoS	
KPI Description	This KPI measures the level of disturbance generated by the renovation works, for each level of the building associated with residential units, broken down into 4 different categories of disturbance, namely: Average Project Utilities Disruption, Average Project Physical Space Disruption, Average Project Internal Environment Disruption and Average Project Traffic Disruption.
Unit	Disturbance levels from 0 (no impact) to 4 (high impact, activity not compatible with the occupant's presence during the works)
Calculation	The calculation is carried out through the identification of the activities necessary to implement the renovation scenario to be assessed. Each activity, associated with one or more RINNO energy efficiency measures, is characterized by a pre-defined sequence of processes, which are themselves characterized by number workers employed, equipment and impacts in the different disturbance categories. The definition of rules for the automatic definition of a GANTT and the association of the activities to the units and/or parts of the building, allows therefore the daily assessment of the different levels of expected disturbance, although in a preliminary way. Below are the algorithms used to calculate the indicators. $$Average\ physical\ space\ disruption(a) = \frac{\sum_{i=1}^{i=n} Physical\ space\ disruption(i)}{Duration(a)}$$ $$Average\ internal\ environment\ disruption(a) = \frac{\sum_{i=1}^{i=n} Internal\ environment\ disruption(i)}{Duration(a)}$$ $$Average\ utilities\ disruption(a) = \frac{\sum_{i=1}^{i=n} Utilities\ disruption(i)}{Duration(a)}$$

	$$Average\ traffic\ disruption(a) = \frac{\sum_{i=1}^{i=n} Traffic\ disruption(i)}{Duration(a)}$$
Sources of information within RINNO	BIM of existing building and renovation scenarios
Source / based on	RINNO specific
Contribution to Expected Impacts:	This KPI contributes to health and wellbeing of tenants. It allows each inhabitant, at a very early stage in the planning process, to assess the impact in terms of disturbance caused by the renovation of different scenarios and to take the necessary remediation actions in advance.

6 Other indicators in the evaluation of renovation works and project impacts

Apart from the KPIs used for the selection of the optimum renovation scenario relevant to the design/planning stage of the renovation there are other KPIs that are used to assess the performance of the installation/retrofit stage. These are outcomes of the RINNO E-Cockpit that are used for the evaluation of the retrofitting process improvement, from a safety, quality, cost, schedule, environmental and social perspective. These KPIs are based on innovative monitoring works along the retrofitting process and are calculated in the frame of WP4 Retrofitting process improvement, they will be numerical, graphic (e.g. time distribution) or arrays and lists:

Category	e-cockpit KPI Description
Safety	Improvement and monitoring of workers safety: Number of safety incidents. Identification and alerts on recurring problems.
Quality	Improvements and monitoring of quality issues: Number and time distribution of quality incidents. Number of customer complaints. Identification and alerts on recurring problems.
Costs	Resource consumption according to progress end-of-construction forecast: Registered cost overruns. Registered savings (reduction in construction cost).
Scheduling	Time and labour consumption according to progress end-of-construction forecast: Number of days for work sequence and delay (vs. planned) gap. Duration for resolving issues. Number of milestones checked.
Environmental	Monitoring of on-site resources and waste: Time distribution of resource consumption. Time distribution of number of garbage container evacuated.
Services and benefits	Monitoring of inhabitants and client satisfaction: Number of customer complaints.
Logistics	Rate of deliveries respecting the schedule. Rate of compliant deliveries (product reference, packaging (by zone/weight limit/ adaptation to logistics means), quantity, condition, transport) Rate of deliveries respecting the reserved slot Distribution of trucks during the day Rate of use of outsourced storage areas Rate of use of storage areas Number of stock-outs on site Duration of storage of materials on the site Good organization of storage areas

From a social perspective, other indicators are calculated in the s-LCA tool, providing a detailed analysis of the implications of renovation works in different categories affecting mainly to tenants. These are mostly relevant to the use phase of the building. Furthermore, some of these indicators are also relevant to the detailed design stage of the renovation (i.e. at a very mature stage where the final specifications of the products and measures are considered) and despite the fact that they are not considered in the selection of the scenario, they are very useful in stimulating/provoking the design team to consider additional factors when finalizing the specifications of the renovation. This is where the s-LCA tool contributes significantly in the design stage and highlights its value in improving the user experience of the renovation. The indicators are listed below:

Category	Social Aspect	Indicator
Accessibility	Access to building services	Arrangement and ease of operation of switches and control systems.
Health and comfort	Thermal characteristics (building)	Satisfaction degree with thermal environment.
		Time outside thermal comfort range.
	Thermal characteristics (user and control system)	Possibility to measure and control the temperature in the building and/or in individual rooms.
		Ability to control operating temperature at building level and/or in individual spaces.
		Ability to control humidity at building level and/or in individual spaces.
		Ability to control air velocity and air distribution at building level and/or in individual spaces.
	Indoor air quality (building)	Declared substances emissions in building materials used.
		Time outside Indoor air quality range.
	Indoor air quality (user and system control)	Existence of ventilation control in the building. Users' ability to control ventilation automatically and/or manually.
		Existence of CO_2 concentration measurements and monitoring in individual spaces.
		Existence of humidity measurement and monitoring in individual spaces.
	Acoustic characteristics	Noise levels of service equipment, such as sanitary and ventilation systems, as well as other environmental noise sources.
	Visual comfort (building)	Daylight contribution: Daylight factor (%)
	Visual comfort (user and control system)	Users' ability to control the amount of daylighting in individual spaces.
Maintenance	Frequency and duration of routine maintenance	Usability of the building while routine maintenance tasks are carried out.
		Health and comfort impact of users during

		maintenance activities.
	Frequency and duration of repairs	Health and comfort impact of users during repair tasks.
		Usability of the building while repair tasks are carried out.
	Frequency and duration of replacements	Health and comfort impact of users during replacement tasks.
		Usability of the building while replacement tasks are carried out.
Safety and security	Resilience to climate change consequences: Wind resistance	Measures to prevent detachment of facade elements.
	Resilience to climate change consequences: Strength to solar radiation	Solar control measures, such as shading, types of window glazing, etc.
		Use of air conditioning, ventilation systems.
	Resistance to Accidental Actions: Seismic Resistance	Installation of shatter-resistant windows.
	Resistance to Accidental Actions: Burning behaviour	Higher fire resistance classes or other measures included in the design to improve the load-bearing capacity, integrity and/or insulation of building elements.
		Use of materials and products with a higher reaction to fire class than required by applicable regulations.
	People and property security from intruders and vandalism	Impact resistance of building envelope to protect against vandalism.

Other KPIs will be analysed for the quantitative and qualitative evaluation of demonstrators (task 6.4), in the context of WP6 Integration, Demonstration, Evaluation and Replication Potential. These will specifically evaluate the impacts of the demonstrators of RINNO project, presented in section 2.1.2 of the Grant Agreement, in terms of e.g PES triggered by the project, reduction of cost of electricity, annual turnover due to RINNO implementation, Payback period, energy decrease, thermal performance of RINNO technologies, cost reduction during design, construction, maintenance, reduction of time, user acceptance, etc. Additional KPIs will also be considered relevant to the advancements on the RINNO technologies achieved by the technology providers (WP2) during the course of the project, such as space saved, use of bio-based materials, use of recyclable material, use of recycled materials, material use avoided

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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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