RINNO PROJECT
Report

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

Deliverable 1.1 (v1): RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9

Work Package 1: RINNO Augmented Intelligence Renovation Framework

RINA-C

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Executive Summary

This report presents the preliminary analysis and definition of stakeholders' expectations from improved renovation processes and innovative technology solutions. It focuses mainly on the needs of tenants and the social, technical and financial barriers and challenges they face. This information is used to define user requirements (RINNO key requirements) to develop appropriate renovation processes and select suitable technology solutions.
In order to develop this first version of RINNO key requirements, the following main activities were conducted to date:

- Conducting a review of other relevant Horizon 2020 projects, RINNO partners' previous experience as well as literature to analyse the key needs, barriers and challenges stakeholders identify about the renovation process (Section 2.2).
- Conducting a literature review to define the typology of renovation works, the main stages in the building renovation process and the key stakeholders involved along the whole value chain (Section 3).
- Launching an online questionnaire to gather additional data about stakeholders' needs as well as the barriers and challenges they face in relation to the renovation process. The questionnaire targeted all stakeholders in the value chain (Section 4.2).
- Selecting RINNO key requirements based on insights from the literature review, questionnaire responses analysis and other WP1 tasks (Section 4.3).
- Matching the RINNO technology solutions with the selected key requirements and indicating the expected impacts of these solutions (Section 5).
- The Roadmap to TRL9 methodology that will be adopted within the RINNO project (Section 5.3)
- Drawing conclusions for the optimization of the energy renovation scenarios in the EU building stock (Section 5.4).

The identified RINNO key requirements are expressed in form of KPIs, which are presented in the 'Report on RINNO KPIs (v1)' (Deliverable 1.6).

Over the coming months, the preliminary list of requirements in this deliverable will be reviewed, taking into account findings of all other technical work packages. The commercialisation roadmaps will be elaborated based on the collection of feedback from stakeholders involved in the pilot demonstration sites and based on the final use case scenarios.

By May 2022 (month 24 of the project), a final version of this report will be presented in 'RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (final version)' (Deliverable 1.2). At the same time, the final set of KPIs will be presented in the 'Report on RINNO KPIs (final version)' (Deliverable 1.7).

The final RINNO key requirements will be fed back into the design process to modify, as necessary, the design specifications, model definitions and engineering tasks.

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Abbreviations List

AEC	Architecture Engineering Construction
BIM	Building Information Modelling
BIPV	Building Integrated Photovoltaic
BPIE	Buildings Performance Institute of Europe
BRP	Building Renovation Passports
DHW	Domestic Hot Water
EC	European Commission
EE	Energy Efficiency
ESCO	Energy Service Company
GWP	Global Warming Potential
KPI	Key Performance Indicator
nZEB	nearly Zero Energy Building
EPBD	Energy Performance of Buildings Directive
EPDM	Ethylene Propylene Diene Monomer
ESCO	Energy Service Company
HVAC	Heating, Ventilation and Air Conditioning
RES	Renewable Energy Systems
RIBA	Royal institute of British Architects
RRR	RINNO Renovation Repository
LON	Local Operating Network
PES	Primary Energy Savings
PV	Photovoltaic
RES	Renewable Energy Systems
RIBA	Royal institute of British Architects

RRR	RINNO Renovation Repository
TRL	Technology Readiness Level
WP	Work Package

1 Introduction

The present report is a public deliverable (Deliverable D1.1 “RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (V1)”) of the RINNO H2020 funded European project, developed in the framework of the activities of Task 1.1 “Elicitation of Stakeholder Requirements & Market Needs”. The main scope of this report is to identify a set of key themes, including requirements, needs, barriers and challenges, from the point of view of different stakeholders involved in the renovation value chain. This will allow to guide stakeholders in the renovation route decision, providing straightforward information on the most promising renovation scenarios and indications from technical, economic, environmental and social perspectives.

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 1.1

The objective of the present Deliverable 1.1 is to collect and analyse stakeholders' requirements in terms of buildings renovation expectations, via a structured methodology providing useful insights to facilitate understanding of expected benefits arising from renovation process optimization.

The framework of this analysis will be developed along two axes:

a) Analysis of the literature documentation and review of the most relevant H2020 project aimed at identifying the typology of renovation works, the main phases in the building renovation process and the key stakeholders involved. In parallel, a literature documentation analysis has been carried out identifying the key stakeholders' needs as well as the barriers and challenges they face in relation to the renovation process. The results of the literature review have been supported by an online questionnaire submitted to the partners involved within the RINNO project and direct contacts in the RINNO network and figures directly involved in the pilot demo site or in general renovation processes (designers, architects, contractors, tenants, technology providers etc..).

b) Definition of specific tables concerning the innovation content and the market potential of the technologies provided by the RINNO project partners. The tables are updated after the first six months of the project and they will be updated along with the project duration in agreement with the project partners. These tables are part of the RINNO Renovation Repository (RRR), and they represent a preliminary step for the development of the TRL9 roadmap understanding the commercialization potential.

While Task 1.1 focuses on the definition of the renovation requirements, needs, barriers and challenges gathering information from different stakeholders of the renovation value chain in the first phase (M1-M6), Task 1.3 focuses on the identification of the renovation requirements of the demo buildings, using as input the tenants' needs and requirements.

The requirements hereby identified will be inputs for other tasks of the RINNO project and will be expressed by relevant groups of KPIs (T1.4). After the successful completion of an iteration cycle, each WP will provide feedbacks to further refine and extend the outputs of this task.

This process will lead to new and/or updated requirements, which will be feedback into the design process in order to enable necessary modifications in the design specifications, model definitions, and necessary engineering tasks.

An analysis of RINNO technologies and a related roadmap to TRL9[1] will be developed as a successive part of this task, aiming to bring the RINNO innovative solutions to their full commercialisation potential. This activity will be based on the results described in the present document and the experience gained from demo sites in the next month of RINNO project implementation, to be included in the second version of the present document D1.2 *"RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (Final Version)"* due at M24 of the project.

[1] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

1.3 Relation to Other Activities

The identification of stakeholders' needs and requirements in terms of buildings renovation expectations is performed through a two-fold approach. On the one hand, the requirements have been collected via direct engagement of stakeholders involved in the renovation value chain by means of a questionnaire described in the present deliverable. On the other hand, a desk search have consolidated the retrieved results in order to provide a more comprehensive and solid output, resulting in a final list of requirements.

In parallel to this, in close collaboration with Task 1.4, a set of KPIs will be identified to quantify the identified stakeholders' needs and requirements. These requirements are expressed by the group of KPIs selected in the Deliverable 1.6.

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

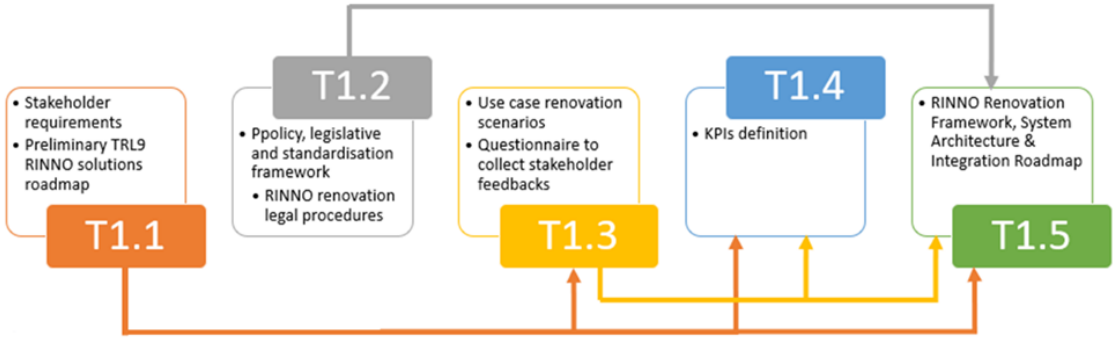

Figure 1.1. RINNO WP1 interaction.

In addition, RINNO Key requirements and needs hereby identified, will be used throughout the project to support the development of the RINNO technologies/solutions and toolkits.

RINNO KPIs (T1.4) will be used throughout the project to support the development of the RINNO toolkits (WP3), the setup an IoT-middleware for the management and control of the buildings (WP5) and the evaluation of demonstrators and technologies performance (WP6).

2 Methodology for collection and analysis of stakeholders' requirements

2.1 Data sources and framework

The methodological framework is based on a review of the literature documentation and the publication of a specific questionnaire for the data collection on the most crucial topics related to renovation with direct involvement of the stakeholders involved in the renovation value chain. In order to collect information among the whole renovation process, the RINNO stakeholders have been identified thanks to the support of the RINNO consortium community, including partners of the RINNO project, direct contacts in the RINNO network and figures directly involved in the pilot demo sites.

The cross-check among the data collected by documentation review and the questionnaires outcomes allowed to obtain a clearer and wider vision along all the renovation value chain. The questionnaire results have been analysed and validated through discussion with the members of the RINNO consortium.

The review of the literature documentation has been conducted in order to study issues related to the renovation value chain and identify previous experiences in the field of reference of the RINNO project, including scientific articles and previous EU funded projects. Moreover, the literature review has been carried out aiming at identifying the typology of renovation works: the main phases in the building renovation process and the key stakeholders involved are defining, in conclusion, a list called RINNO Key Requirements.

In support of the literature review, **the online questionnaire** has been conducted in order to collect relevant information from the main invovled stakeholders in the renovation value chain through direct contact. The questionnaire is aimed at collecting useful data to identify main requirements, needs, barriers and challenges from actors directly involved in the renovation process; the questionnaire has been launched to collect information across European and non-European countries through the channels and networks of contacts of the partners of the RINNO project.

2.2 Relevant H2020 projects for the scope of the document

Starting from the RINNO partners' previous experience, as well as a landscape analysis on past and currently ongoing EU funded projects, a list of reference projects that are targeting one or more of the topics under investigation within this document was defined.
The selected projects are investigating different aspects about the building renovation processes and have been studied to set the basis for the RINNO project activities. In particular, the references included:

- Analysis of the **renovation value chain**, identifying and clustering stakeholders into a series of categories and characterizing their role within the process;
- Analysis of the **needs and requirements of different stakeholders' categories** and description of expected improvements or benefits deriving from renovation;
- Analysis of **existing barriers** for deep renovation across Europe, in general, and from the point of view of involved actors.

The extensive analysis included the selection of relevant documentation from a wide range of EU funded projects from FP7 and Horizon 2020, as well as Collaborative Interreg SUDOE (e.g. ENERBUILCA, URBILCA) and IEE projects (e.g. ENSLIC, AIDA), including but not limited to projects seeing the participation of RINNO's partners.

The list of identified projects and most relevant documents adopted as a reference within the present work is reported in the following Table 2-1.

Table 2-1: List of reference projects and synergies with the present work.

Relevant EU projects	Synergies with RINNO D1.1
BuildHEAT[2] (H2020-EeB-08-2015, ongoing project) [CIRCE/ PINK - Partners]: BuildHEAT carries out deep building renovations in 3 demo sites in EU where a set of reliable, energy-efficient and affordable retrofit solutions for multiple-occupancy residential buildings.	The BuildHEAT Project focuses on the human factor: the experiences of residents in relation to heating and cooling, and the impact of retrofit measures upon their comfort, health and practices. *D5.2 - Managing Human Factors in Retrofit Projects*[3] discusses the effective management of human factors during retrofit projects. *D6.4 – Financing models for deep retrofit actions*[4] illustrates the financing models for the deep energy retrofit of existing buildings, including a detail on the needed interactions among involved stakeholders.
NEED4B[5] (FP7-EeB.ENERGY.2011.8.1-1, closed project) [CIRCE –Coordinator, RINA-C – Partner]: NEED4B developed an open and easily replicable methodology for designing, constructing, and operating new low energy buildings, aiming to a large market uptake.	Although the NEED4B project primarily targeted new buildings, some information on the actors involved in the process can be mutated to renovation, particularly referring to *D2.8: Final version of the methodology after the design, construction and monitoring program*[6]. Moreover, the methodology used for LCA and LCC analyses provided useful reference for renovation steps definition *D2.5 LCA and LCC during the design, construction and operation phases*[7]
OptEEmal[8] (H2020-EU.2.1.5.2, closed project) developed an Optimised Energy Efficient Design Platform able to design energy efficient retrofitting projects that are based on different energy conservation measures to improve the behaviour of a district.	*D6.3 Report on stakeholders and IPD implementation to demonstrate the OptEEmAL platform*[9] describes the stakeholder's involvement in the development and the demonstration of the platform, based on a structured methodology for stakeholders' identification.

[2] BUILDHEAT project website: http://www.buildheat.eu/
[3] BUILDHEAT "*D5.2 - Managing Human Factors in Retrofit Projects":* http://www.buildheat.eu/wp-content/uploads/2020/05/D5.2-Managing-the-human-factors-in-retrofit-process.pdf
[4] BUILDHEAT "*D6.4 – Financing models for deep retrofit actions*": http://www.buildheat.eu/wp-content/uploads/2020/05/WP6-D6.4-Financing-models-for-deep-retrofit-solutions.pdf
[5] NEED4B project website: http://need4b.eu/
[6] NEED4B "*D2.8: Final version of the methodology after the design, construction and monitoring program"*: http://need4b.eu/wp-content/uploads/2018/02/NEED4B_D2.8_Final-version-of-the-methodology-after-the-design-construction-and-monitoring-program.pdf
[7] NEED4B *"D2.5 LCA and LCC during the design, construction and operation phases"* http://need4b.eu/wp-content/uploads/2018/02/NEED4B_D2.5_LCA-and-LCC-during-the-design.pdf
[8] OptEEmal project website: https://www.opteemal-project.eu/
[9] OptEEmal "*D6.3 Report on stakeholders and IPD implementation to demonstrate the OptEEmAL platform*": https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c1fd1fc8&appId=PPGMS

Relevant EU projects	Synergies with RINNO D1.1
ENERGY IN TIME[10] (FP7-EeB.NMP.2013-4, closed project) [CIRCE – partner] developed a simulation-based control tool that increases energy efficiency during building operations and maintenance.	The project identified the importance of providing comfort to residential customers, developing services and solutions aimed at this objective. The proposed tools and services are described in a scientific article[11].
STUNNING[12] (H2020-EU.2.1.5.2, closed project) [RINA-C – partner] supported the collaboration among the stakeholders operating in the deep renovation of buildings.	Stakeholders' community was involved through the realization of a community platform. A detailed study on barriers affecting energy renovation was performed and reported in *D4.1 – Energy Efficiency renovation market mechanisms, trends and barriers*[13].
BIM4Ren[14] (H2020-EU.2.1.5.2, 2018-2022) is developing a BIM-based approach and tool to target energy renovation of existing buildings with a focus on the involvement of the whole construction value chain.	The project developed a structured clustering of main typologies of renovation works, that is analysed in the present document, starting from *D1.1 Stakeholders requirements and constraints, Building Information Modelling based tools & technologies for fast and efficient RENovation of residential buildings*[15]. Moreover, *D2.2 List of Designers' Needs and Requirements for BIM-Based Renovation Processes* identified in detail the needs and requirements of different stakeholders involved in renovation and provided useful reference to this study.
POCITYF[16] (H2020-EU.3.3.1.3 – ongoing, 2019-2024) [RINA-C, CERTH, CIRCE, EGC, VTT partners] sustain lighthouse cities across Europe in the implementation of innovative technologies for energy and district management. The project offers inclusive and holistic services for interdisciplinary stakeholders and citizen engagement.	The project adopted a structured methodology for stakeholders' categories identification and engagement. With reference to *D1.1: End-User and Stakeholders Requirements Definitions*[17],the structure was used as reference for the selection and characterization of stakeholders' categories in the present work.

[10] ENERGY IN TIME project website: https://www.energyintime.eu/
[11] Gómez-Romero, J.; Molina-Solana, M.; Ros, M.; Ruiz, M.D.; Martin-Bautista, M.J. Comfort as a Service: A New Paradigm for Residential Environmental Quality Control. Sustainability 2018, 10, 3053. https://doi.org/10.3390/su10093053
[12] STUNNING project website: https://stunning-project.eu/
[13] STUNNING "*D4.1 – Energy Efficiency renovation market mechanisms, trends and barriers":* https://renovation-hub.eu/wp-content/uploads/2019/09/D4.1_FINAL-15.pdf
[14] BIM4Ren project website https://bim4ren.eu/
[15] BIM4Ren *"D1.1 Stakeholders requirements and constraints, Building Information Modelling based tools & technologies for fast and efficient RENovation of residential buildings":* https://bim4ren.eu/download/d1-1-stakeholders-requirements-and-constrains/
[16] POCITYF project website https://pocityf.eu/
[17] POCITYF "*D1.1: End-User and Stakeholders Requirements Definitions":* https://pocityf.eu/wp-content/uploads/2020/09/POCITYF-864400_D1.1_End-User-and-Stakeholders-Requirements-Definition-1.pdf

Relevant EU projects	Synergies with RINNO D1.1
EuroPHit[18](-) [-] was aimed at increasing the quality and energy efficiency of step-by-step refurbishment of buildings throughout the EU by developing methodology and implementing uniform quality assurance from the design to the construction phase.	The project provided relevant information to guide thought the renovation process, with reference to the building renovation stages (step-by-step), particularly within the document *"Handbook for step-by-step retrofits with Passive House Components"*[19]

2.3 Questionnaire methodology and overall structure

Starting from the scenario identified through desk search, an online questionnaire was set up. The questionnaire aims at gathering information about the common practices and the main concerns of the stakeholders involved along each stage of the building renovation value chain, so the current identified barriers and the technology scenarios could help to improve the entire processes. The goal is to define and evaluate key requirements for each of the stakeholders' categories involved in the renovation process.
The possibility to directly engage actors involved in the renovation process, i.e. different stakeholders operating along the value chain, provide high-value references as well as useful insights from primary sources. This will support the information gathered from the desk search and provide additional details and in-depth opinions on investigated subjects.

The questionnaire was designed through the European Commission tool EUSurvey (link to the questionnaire). The questionnaire was active from the 1st October 2020, the results of the questionnaire were analysed on the 30th October and updated on the 20th November 2020.
In order to expand the number of collected answers a second round was launched, on February and March 2021, collecting a total of 82 answers of which 64 completed with relevant outcomes for the analysis. The questionnaires involve more than 10 countries, with companies of different sizes and expertise in the renovation field and representing the main roles in the construction sector (Designer, contractor or subcontractor, building owner or resident, public administration as regulator entity or Industrial). The results are analysed in detail in the present document.

The target group of the RINNO questionnaire are the members of the AEC sector, working on large, medium and small enterprises, public bodies, and also self-employees. In principle, the questionnaire is addressed to all countries, although the way of distribution might limit the scope mainly to European countries.

The on-line questionnaire has reached the RINNO consortium members, RINNO Extended stakeholders' community, as well as other recipients involved in the renovation value chain. The questionnaire has been distributed to the target groups, thanks to the members of RINNO consortium through direct emails reaching contacts across Europe and even non-European countries.

The questionnaire is designed to target different stakeholders of the renovation process value chain (see section 2.3). It includes conditional questions that allow to show or not other questions, on the basis of the given answers in order to provide the needed granularity and collect relevant information on the basis of stakeholders' expertise.

[18] EuroPHit project website: https://europhit.eu/
[19] EuroPHit - Handbook for step-by-step retrofits with Passive House Components https://europhit.eu/sites/europhit.eu/files/EuroPHit_Handbook_final_Optimized.pdf

The questionnaire (reported entirely in Annex 2) is structured in four sections, hereby briefly described.

(a) Section 1 - Scope of study description and data privacy policy
The initial page of the questionnaire is to describe the scope of the study and privacy policy.

(b) Section 2 - General Information about respondents' organization
The objective of this section is to reach a general understanding about respondents' role in the renovation process and, eventually, details on the type of organization they work for.

(c) Section 3 - Identification of stakeholders' key requirements and needs
The objective of this section is to map stakeholders' requirements from different perspectives, according to the role of respondents along the value chain. Moreover, the section assign an "importance scores" to requirements and needs identified.

(d) Section 4 - Potential to overcome the barriers and challenges in renovation process through technology
The objective of this section is to identify how technologies can help to overcome the barriers and challenges in renovation processes and to define the requirements that technology must have to meet the demands of the respondent as a part of the renovation process. The section collect a rating on most relevant Social and Technical barriers and challenges identified for the deep renovation process in order to evaluate their relative importance for the stakeholders directly involve along the process.

3 Overview of Renovation Process Value Chain

3.1 Typologies of Renovation Works

A refurbished and improved building stock in the EU will promote the utilization of decarbonised and clean energy systems, as the building sector is one of the largest energy consumers in Europe and is responsible for more than one-third of the EU's emissions[20].

In order to foster energy efficiency building renovation, an urgent need for an integral building energy retrofitting approach is required, from the data acquisition to the design phase. The general object is to reduce the renovation operations time and to maximise the results obtained in terms of energy efficiency assuring at the same time, the adequate level of comfort to occupants.

Building renovation can be defined as the structural and technical repair or modernization of one or several spaces or even the entire existing structure. Renovation interventions can be classified according to different levels, on the basis of the "depth" of renovation carried out.

In particular, it is possible to distinguish between two categories of renovation[21]:

- **Partial renovation or service**: represented by periodic maintenance works aimed at maintaining an optimal building status through repairing and solving structural defects or bring something back to its original status including the energy efficiency levels;
- **Deep renovation or deep retrofit**: including the replacement of outdated equipment with new technologies or the modernisation of a building area by following modern construction techniques aimed at improving the energy performance.

More specifically, the Energy Efficiency Directive (Directive 2012/27/EU)[22] defines 'deep renovations' as *"renovations which lead to a refurbishment that reduces both the delivered and the final energy consumption of a building by a significant percentage compared with the pre-renovation levels leading to a very high energy performance".*

Deep renovation or deep retrofit intervention includes a series of renovation works, targeting different aspects and elements of the building in order to provide a comprehensive refurbishment and an overall impact on performances.

According to the study carried out in the framework of the following EU funded projects BIM4Ren[15], NEED4B[7] and EuroPHit[19], a solid identification and clustering of the main typologies of renovation works and interventions has been defined along all the renovation process value chain. The main typologies of renovation works and intervention identified in the previous mentioned studies are presented in the following Table 3-1. These typologies will be considered as the reference from now on in the framework of RINNO project activities.

[20] Renovation wave, 2020, available at: https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en
[21] Global Buildings Performance Network - What Is A Deep Renovation Definition? – Technical Report – 2013 https://www.gbpn.org/sites/default/files/08.DR_TechRep.low_.pdf
[22] Energy Efficient Directive, available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:en:PDF

Table 3-1. Main Typologies of Renovation Works

#	Main Typologies of Renovation Works	Included Renovation Works
1	**Maintenance and Inspection Works**	• Energetic analysis and audit: data gathering related to the energy use and general needs of the building that can satisfy all the inputs necessary for the renovation analysis; • Technical Inspection of the building: the existing building typology is analysed and classed by age, by uses and occupants, by geometry and flatness, and by material composition
2	**Internal refurbishments**	• Painting • Floor / Wall tiling • Partition and internal space remodelling • Wet-rooms (bathroom, kitchen…) remodelling
3	**Interventions on the envelope**	• Framing and glazing replacement • Façade retrofitting • Roof retrofitting • Underground rooms
4	**Structural intervention**	• Column & Beams • Slabs • Load bearing Walls • Foundations
5	**Service improvement / addition**	• Heating, Ventilation and Air Conditioning (HVAC) • Renewable Energy Sources (RES) • Electricity • Plumbing and Sewage • Fire security
6	**Accessibility**	• Elevator incorporation • Adaptation of main access to buildings (ramps)

3.2 Building Renovation Stages

In order to extract a clearer and wider overview of the building renovation, an analysis of the main stages in the building renovation process has been carried out taking into account as reference the guideline defined by the Royal Institute of British Architects (RIBA) [23], that since 2007 is directly involved on the definition and review of the Plan of Work in the building renovation industry; the Plan is focused on process briefing, designing, constructing and operating building projects into eight stages and explains the stage outcomes, core tasks and information exchanges required at each stage. With more than 28.000 professional members, RIBA Plan of Work represents a relevant reference in the field of building renovation and construction, the guideline has been updated constantly over the years with three main editions: 2007, 2013 and the most recent 2020[24].
The renovation stages proposed by RIBA are reported in Table 3-2. Within the framework of the RINNO project, some of the RIBA stages have been slightly revised and adapted as proposed in the table below.

[23] The Royal Institute of British Architects is a global professional membership body in architecture.
[24] RIBA Plan of Work 2020 Edition - https://www.architecture.com/-/media/GatherContent/Test-resources-page/Additional-Documents/2020RIBAPlanofWorktemplatepdf.pdf

Table 3-2: RIBA Renovation Stages and RINNO Renovation Stages

# Stage	RIBA Stages name	Stage description	RINNO Ren. Stages Name
Stage 0	Strategic Definition	The project is strategically evaluated and defined before the production of a detailed brief. This is particularly relevant in the context of sustainability and deep renovation taking into account the client requirements.	Strategic Definition
Stage 1	Preparation and Brief	Within this stage, an initial project brief and any related feasibility studies to help enable the development of the concept design are proposed and approved by the client. The stage also involves the 'preparation tasks' such as assembling the project team and defining each roles and responsibilities.	Information gathering and audit
Stage 2	Concept Design	The initial concept design is created in line with the design brief established in stage 1-2 and presented to the client.	Renovation Conceptual Design
Stage 3	Developed Design	The conceptual design from Phase 2 will be further developed to meet customer needs. Upon completion, plan drawings and documents (if required) will be drafted and submitted to local authorities for approval. Once approved, the design of building services and structural engineers will begin to develop, and more detailed cost and project budget analysis can be performed.	
Stage 4	Technical Design	The structural and building services packages are further refined allowing for any specialist sub-contractor design to be carried out. The architect will consult with the local building regulations officer and prepare the detailed technical design package with the specifications. At the end of this stage, traditionally the project will be issued to the chosen group of contractors/builders for tender. Once the tenders are received, the quotations will be assessed and analysed before one is chosen ready to start the construction work stage.	Renovation Technical Design
Stage 5	Construction to Practical Completion	In this stage, the building will be constructed based on the drawings and information generated in the previous stages, and it is usually managed by architects to ensure the smooth progress of the construction process.	Construction
Stage 6	Handover and Close Out	This stage facilitates the smooth completion of the handover of the project. This stage involves the inspection of the finished project and any defects will be corrected before the certification phase.	Handover and close out
Stage 7	In Use	Post-occupancy evaluation and review of project performance as well as new duties that can be undertaken during the In-Use period of a building.	In use

The detailed scheme of stages according to the planning work set by RIBA is illustrated in Annex 1 of this document.
According to the previous definitions and the standard definitions of RIBA phases and review documentation on the renovation process, the phases considered finally in the RINNO project, and particularly to be used in the questionnaire (Section 4.2) and are the following ones:

Table 3-3: RINNO Project Renovation Stages

RINNO Project renovation stages
Strategic Definition
Information gathering and audit
Renovation Conceptual Design
Renovation Technical Project
Construction
Handover and close out
In use

3.3 Analysis of Stakeholders Involved in the Renovation Process

The main objective of the analysis of the stakeholders involved in the renovation process is to identify the whole renovation/construction value chain focusing on the stakeholder's roles and understanding their expectations along all the renovation process since the very first stage throughout project implementation and building use phase.

The identification of the stakeholders' groups will be the starting point for requirements gathering within RINNO project activities. Moreover, this classification will allow grouping the collected requirements, constraints, barriers and challenges by type of stakeholder and its role along the renovation value chain.

Aapaoja et al.(2014) in their paper *"A Framework for Stakeholder Identification and Classification in Construction Projects"*[25], describe a methodology aimed to support project management in stakeholders' identification and classification, providing useful indications for requirements engineering, to be taken into account particularly at the beginning of a project. According to the authors, stakeholder groups can be defined on the basis of their role and relation to the project, as described in details in Figure .

Figure 3.1. Stakeholder classification in the renovation value chain. Source: Aapaoja et al.(2014)

The analysis of stakeholders' categories is a common methodology adopted in EU funded projects to identify and engage people and organization directly involved in the field or sector of interest. A detailed analysis of the approaches and methods adopted in the framework of

[25] Aapaoja A., Haapasalo H., A Framework for Stakeholder Identification and Classification in Construction Projects. Open Journal of Business and Management, 2014, 2, 43-55.

previously conducted renovation R&I projects was performed, with particular reference to the list of EU funded project presented in Table 2-1.

The gathered information allowed to define the stakeholder's categories involved along the renovation value chain that has been represented in the Stakeholders Map of Figure 3.2 and described more in detail in the following Table 3-4.

The categories hereby identified were the primary target for questionnaire distribution, according to the methodology outlined in Chapter 2.3. This was intended to collect renovation requirements by different actors operating along the renovation value chain.

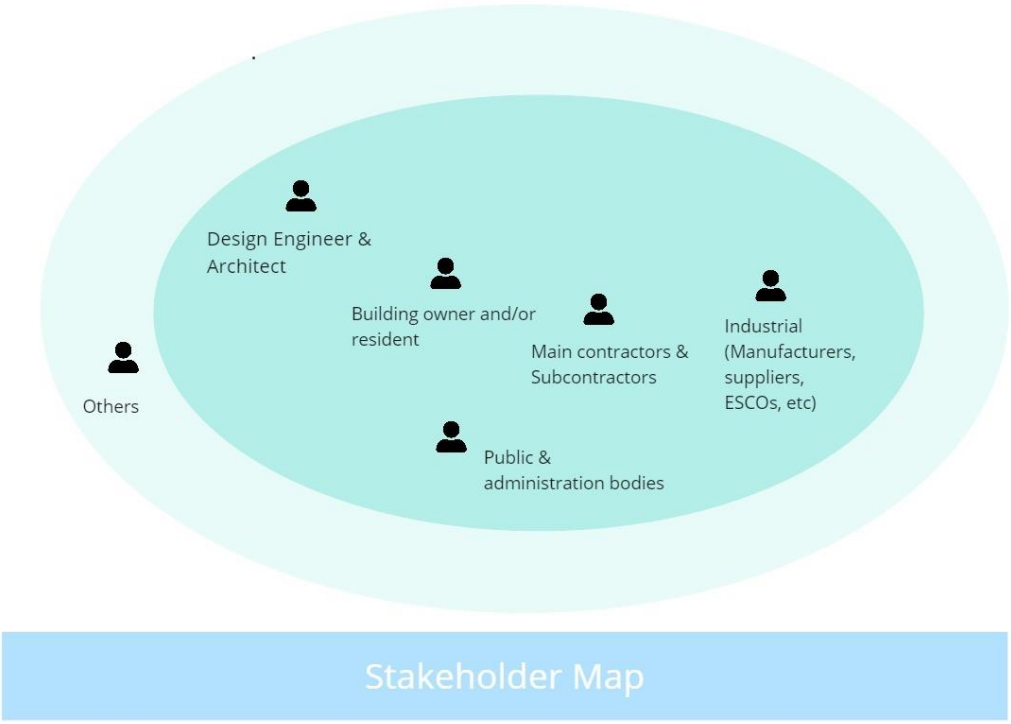

Figure 3.2. Stakeholder Map of Renovation Value Chain

Table 3-4. Definition of Stakeholders in the Stakeholders Map[26]

Stakeholders Group	Role
Designers • Project Manager • Architect • Structural Engineer • Audit and data gathering • Services Engineer • Work controller	The project manager is the main responsible for the project design and development activities based on customers requirements. He is in charge to develop design documentations, technical specifications and other project related documentations as needed. Moreover he is in charge of analyzing design issues and suggest corrective actions, integrating other contributions to the final design. Other stakeholders in this category, such as Services engineers are responsible for the Design discrete and technical subsystems, such as HVAC, structural, electricity, and automation

[26] Aapaoja A., Haapasalo H., A Framework for Stakeholder Identification and Classification in Construction Projects. Open Journal of Business and Management, 2014, 2, 43-55.

Stakeholders Group	Role
Contractors and Subcontractors • Data gathering (scanner 3D, inspection, on-site measures, material tests.,) • On site worker • Cost controller • Quality controller • Installer • Security manager • Site manager	The contractor (often a building company in combination with an ESCO) is the professional who implements and maintains the energy efficiency solutions adopted for the building/dwelling. The main contractor is responsible for the construction activities, the management of sub-contractors and the communication of information to all involved parties throughout the course of a building project. Sub-contractors work for the main contractor. They perform small, straightforward and discrete tasks, such as painting, ceiling contracting, wallpapering, and floor tiling.
Building owners, residents and occupants • Home owner • Housing associations (as an owner) • Resident/Occupants/tenants • Property owners (social housing association), • Building manager • Building administrator • Facility manager/ Maintenance	Building owners, residents and occupants represent another stakeholders' category involved in the renovation process. Building Owner means the person, company, corporation or authority that holds title to the subject building or facility. Residents are the people living in the building to be renovated and, together with neighbours, may express some requirements or requests for the project. Building occupants include people who spend extended time periods within the building, especially in non-residential buildings (e.g. offices, hospitals, educational buildings, etc.) Regarding building ownership, different configurations are possible, including private ownership (e.g. condominium, building owners or single houses owners, etc) or public ownership (e.g. social housing organizations, public administrations). In the case of social housing, the main initiator of the renovation project is the public administrator and the benefit accrues to the community. They are responsible for the final decision making in the project. They define the project's purpose and the end users' constraints. They usually have the most comprehensive knowledge about the property and an understanding of the actions to be carried out.
Public bodies & administration • Council/local authority • Security authority • Waste manager • Fire service • Planning authority • Health authority	Local and public authorities supervise the project and may set constraints on its execution, with reference to the following subjects: supervision of construction, planning division, fire authority, and health authority. Authorities are responsible for formulating and maintaining regulations, standards and policies and monitoring the adherence to them. Moreover, public authorities are responsible for issuing incentives to promote the adoption of energy efficiency measures in the residential sector. Incentives can reduce the initial investment by the owners, or increase the yearly cash flow through a direct yearly payment or tax deductions.

Stakeholders Group	Role
Industrials • Material suppliers and manufacturers • Technology suppliers and manufacturers • ESCOs	Material suppliers: Supply material and equipment, such as concrete, windows, furnishings, and research instruments. They can be the same as the manufacturers. Material manufacturers: they take over the manufacturing of components, elements or materials according to the specifications defined in the Project. Energy service companies (ESCOs) provide services related to energy management, including designs and implementation of energy savings projects, retrofitting, energy conservation, energy infrastructure outsourcing, power generation and energy supply. ESCOs have also the required financial resources to cover the costs of an energy efficiency project, but they can also have the capability to involve third party financing.
Others • Software developer or consultant • External certificatory • Funders and financial entities • Education and training providers on renovation value chain	Software developer & external consultant: they support the Designer Team in the design and assessment of the building through the specific use of tools or software for the purpose required. The external consultants provide the consultancy advice for the projects on designing, evaluating the cost and technical issues/advice. External certificatory is responsible for validating the project regarding different criteria set by the end-users (i.e. energy classification). They are able to provide standard labels for the final product or the process. Financial entities: A financial institution can be, for example, a bank, a fund, a public or a private entity, and it provides the necessary financial resources to the owner to pay the contractor for the retrofit of the property. They usually do not have specific requirements for the project.

4 Identification of the Requirements & Needs, Barriers and Challenges in the Renovation Process

4.1 Literature Review for requirements identification

In order to collect the key requirements and the needs along the entire building renovation value chain, a desk search analysis was performed taking into avvount different perspectives. Special attention was given to point of view of the stakeholders' category of building owners, residents and occupants. Within the analysis, the needs and requirements of the latter category have been compared with the needs and requirements of other categories such as designers, public bodies, contractor etc.. The desk search analysis has been based on two principal streams: literature analysis (scientific papers and relevant documents on building renovation from other relevant H2020 projects) and RINNO partners previous experience.

4.1.1 Key Requirements and Needs of Stakeholders

4.1.1.1 Key Requirements and Needs of Building Owners, Residents and Occupants Stakeholders' Category

The selection of requirements started considering the stakeholders' category of building owners, residents and occupants. In fact, the role of this category is of primary importance for the renovation process, for two main reasons:

- Building owners act as **prime movers** in the renovation process, deciding to engage in the renovation. The understanding of their needs as well as their expectations gave relevant indications on how much they are prepared to pay, what sort of payback period they will accept, and what approach or technologies could suit best.
- Residents and occupants are the **first interface** with renovation works. Their daily life is changed and impacted by renovation works and the importance of taking care of their comfort along the renovation process as well as during the use phase of the building is fundamental.

For these reasons, successful renovation needs to be "human-centred" in terms of its design, delivery and use[3]. Evidence suggests that poor understanding of human factors can lead to the failure of retrofit projects in terms of the delivery or their long-term performance against their desired objectives[27] [28]. These aspects are even more important when coming to costs definition: it is fundamental to understand the owners requirements also in terms of budget as well as of spending intentions.

Starting from these evidences, the main requirements for each stakeholders' category were identified.
The analysis firstly aimed at the exploration of the topic of energy efficiency in buildings, with particular reference to requirements related to **building occupancy and occupants' behaviour**. In fact, according to IEA (2018) [29], ineffective design choices are often based on models in which occupant behaviour is assumed to remain constant or is left out of the equation. Better design choices should instead consider the variability of occupant behaviour,

[27] Brown, P., Swan, W. and Chahal, S., 2014. Retrofitting social housing: reflections by tenants on adopting and living with retrofit technology. Energy Efficiency, 7(4), pp.641-653.
[28] Seligman, C., Darley, J.M. and Becker, L.J., 1978. Behavioral approaches to residential energy conservation. Energy and buildings, 1(3), pp.325-337.
[29] International Energy Agency, 2018, *"Occupant behaviour-centric building design and operation EBC Annex 79",* available at: https://annex79.iea-ebc.org/

in order to **provide better predictions** of how buildings perform during the operation phase.

It is not guaranteed that during **building occupation,** the indoor conditions of the building will remain as designed. This is especially the case when new technologies are installed in buildings, including insulation and HVAC systems, and when high levels of building efficiency are targeted via the adoption of sophisticated control systems. **Changes in comfort expectations** and in **occupancy trends** (such as teleworking, co-working, and home-sharing) from building occupants often result in an increased impact on energy consumption, compared with design expectations.
The concept of human-centred renovation is concerned with the consideration of the domestic renovation project as a service that is being delivered to an occupant rather than a technical solution to an issue of energy consumption. In this way, energy-efficient renovations should be considered as a **socio-technical problem**[30] [31].
A wide range of needs and requirements could move building owners and occupants to promote a renovation process, the most recurring and relevant could be traced back to the categories of the following list:

- **Economic**, i.e. to reduce energy consumption[3].
- **Environmental** targets and values, i.e. for environmental reasons such as climate change[32]
- **Aesthetics**, i.e. to improve the physical or design quality of the building[33].
- **Life stage**, i.e. to face a change in life including the composition of the household, such as the presence of young children.[34]
- **Comfort and Health**, i.e. to improve the comfort of the home or to relieve symptoms of chronic illnesses[35].

In relation to the last point, air management is a relevant aspect to be managed. Across the EU, people currently spend approximately 90% of their time indoors[36]. Conditions in these environments – **temperature, lighting, humidity, draughts and noise**– play a fundamental role in occupants' physical and mental wellbeing. More efficient buildings **improve thermal comfort** for lower volumes of energy consumption, in turn **reducing emissions** and leading to **better air quality both indoors and outdoors**.
In 2018, exposure to indoor air pollution was recognised by United Nations as one of the main health risk factors that needs to be controlled and reduced[37]. Most outdoor air pollutants penetrate into our homes, work and schools and can react with indoor air pollutants.
For these reasons, an optimal air quality management is a key to improve residents comfort and health.

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[30] Swan, W., 2013. Retrofit innovation in the UK social housing sector: a socio-technical perspective. Retrofitting the Built Environment, pp.36-52.
[31] Tweed, C., 2013. Socio-technical issues in dwelling retrofit. Building Research & Information, 41(5), pp.551-562.
[32] Fink, H.S., 2011. Promoting behavioral change towards lower energy consumption in the building sector. Innovation: The European Journal of Social Science Research, 24(1-2), pp.7-26.
[33] Sherriff, G.A. and Swan, W., 2016. Greater Manchester green deal communities programme scheme exit paper.
[34] Haines, V. and Mitchell, V., 2014. A persona-based approach to domestic energy retrofit. Building Research & Information, 42(4), pp.462-476.
[35] Howden-Chapman, P., Crane, J., Matheson, A., Viggers, H., Cunningham, M., Blakely, T., O'Dea, D., Cunningham, C., Woodward, A., Saville-Smith, K. and Baker, M., 2005. Retrofitting houses with insulation to reduce health inequalities: aims and methods of a clustered, randomised community based trial. Social science & medicine, 61(12), pp.2600-2610.
[36] European Environment Agancy, 2020, "Air quality in Europe", available at: www.eea.europa.eu/publications/air-quality-in-europe-2020-report
[37] United Nations , 2018, "Political declaration of the third high-level meeting of the General Assembly on the prevention and control of non-communicable diseases", available at: www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/73/2

Another relevant perspective, that reflects on a recurrent requirement by building owners and occupants is related to the **durability** of the installed solutions. Any renovation intervention generates its benefits over a long period. Many products have 20-year life spans in which savings are made. However, there are a number of issues that need to be addressed if long-term benefits are to be maintained[38]. This is a consideration that technology providers have to consider: technology packages should be robust where maintenance is unlikely to be frequent.

Coming to non-residential buildings, some additional considerations can be reported to complete the overview on the requirements for owners and occupants, particularly referring to the latter category. A recent study by the Buildings Performance Institute of Europe (BPIE, 2019) found that deep energy renovations deliver specific benefits across different building types. The study clearly identifies these benefits, providing evidence of the impacts delivered to different building occupants, based on their specific needs[39]. The results of the study are summarized in the following points, for most representative categories of non-residential buildings.

- **Public buildings and offices**: In 2019, around 36% of the EU workforce, 81 million people, spend eight hours a day or more working in offices, where about 90% of operating costs are linked to employees presence. Although Covid-19 pandemic introduced and enhance a more agile way of remote working, according to experts, offices will continue to play a relevant role for companies as an embodiment of their brand and culture[40]. Renovating for comfortable, healthy, well-lit and thoughtfully designed workspaces improves staff morale and reduces turnover.
- **Hospitals:** It was found that good ventilation reduces the risk of cross-infection, while daylighting, thermal comfort and good soundproofing accelerate patient recovery times. The BPIE study found that improved indoor environmental quality at a children's hospital would lower mortality rates by 10%. More broadly, energy renovations could cut the average length of patient stays by 11% while also shaving medication costs and employee turnover by 20%.
- **Schools and education:** Student health, attendance, concentration and learning performance all suffer when school buildings are poorly designed or have outdated systems. Modelling carried out by the BPIE estimates that school renovations could allow students to improve academic performance by 3%-8%.

On the basis of the above reported information and in accordance with RINNO partners previous experience, a list of key requirements and needs for the stakeholders' categories from building owners, residents and occupants groups, was identified. The list is organized into three different categories of key requirements and needs, namely "Health, comfort and safety" (HS), "Environmental" (EN) and "Optimized economics" (OE).

Table 4-1 reports the list of key requirements and needs of the stakeholders' group of building owners, residents and occupants.

Table 4-1.Building owners, residents and occupants Stakeholders' Category Key Requirements and Needs

#	Health, Comfort and Safety

[38] Hens, H., 2010. Energy efficient retrofit of an end of the row house: confronting predictions with long-term measurements. Energy and buildings, 42(10), pp.1939-1947.
[39] BPIE (2019), "Building 4 People: Valorising the Benefits of Energy Renovation Investments in Schools, Offices and Hospitals", available at: http://bpie.eu/publication/building-4-people-valorising-the-benefits-of-energy-renovationinvestments-in-schools-offices-and-hospitals/
[40] Arup Group, 2020, Future of offices: in a post-pandemic world, available at: https://www.arup.com/-/media/arup/files/publications/f/future-of-offices-in-a-post-pandemic-world.pdf

R-HS-01	Aesthetics (Building Aesthetics, Landscape Aesthetics, Aesthetical environment)
R-HS-02	Air infiltration rate (Building Air tightness, Systems and HVAC airtightness)
R-HS-03	Indoor Air quality improvement (Mechanical ventilation, Low-emitting materials, Indoor chemical & pollutant source control, Thermal Comfort improvement, Under cooled periods, Over heated periods, Operative Temperature, Humidity, Adaptive comfort approach, Moisture Comfort improvement)
R-HS-04	Thermal Comfort improvement (Under cooled periods, Over heated periods, Operative Temperature, Humidity, Adaptive comfort approach, Moisture Comfort improvement)
R-HS-05	Acoustic performance improvement (Acoustic quality)
R-HS-06	Daylight and views improvement (Illumination levels, % of space with natural light and views, Glare control)
R-HS-07	Ergonomic Workplace improvement
R-HS-08	No need for the resident to leave the building during the works
R-HS-09	Adaptation to changes in comfort expectations and in occupancy trends (such as teleworking, co-working, and home-sharing)
R-HS-10	Building Safety (Earthquake resistance, Tornado resistance, Flood resistance, Fire safety, hazardous material elimination, Electrical safety, Slip and trip protection)
#	**Environmental**
R-EN-01	Energy Consumption
R-EN-02	Energy delivery performance
R-EN-03	Energy uses disaggregation in conditioned space
R-EN-04	Energy uses disaggregation in not conditioned space
R-EN-05	Total CO_2 emission /reduction
R-EN-06	Other pollutant emissions reduction (NO_x, SO_x & particulate matter emissions)
R-EN-07	Share of energy sources (Solid energy fuels, LNG, fuel, renewable energy source)
R-EN-08	Eco labelling (LEED, BREEAM, CASBEE...) of the building after renovation
#	**Optimized Economics**
R-OE-01	Technology R&D Cost
R-OE-02	Labor Cost
R-OE-03	Financing Cost
R-OE-04	Technology Application Cost
R-OE-05	Technology Designing Cost
R-OE-06	Technology Maintenance Cost
R-OE-07	Facility Management Cost
R-OE-08	Space & Infrastructure Costs
R-OE-09	People & Organization Costs
R-OE-10	Outdoors Costs
R-OE-11	Cleaning Costs
R-OE-12	Workplace Costs
R-OE-13	Primary activities specific Costs
R-OE-14	Logistics Costs
R-OE-15	Business support Costs
R-OE-16	Reduction of Energy Consumption

R-OE-17	Length of Payback Period
R-OE-18	Energy-Saving Consciousness of Occupants
R-OE-19	Level of Marketization of Technology and Product- Marketability
R-OE-20	Level of Massive Development of Technology and Product
R-OE-21	Longer building lifetime
R-OE-22	Increase in the building value

4.1.1.2 Key Requirements and Needs of Other Stakeholder Categories

In this section, the key requirements and needs of other stakeholders' categories have been analysed in order to define the basic characteristics for each the identified categories. The analysis is based on a desk search, strengthen by the RINNO partners previous experience in the field of deep renovation.

Designers

Starting from the designers group, it is possible to collect and analyse a series of basic needs and requirements typical of this stakeholders' category. The role of designers is to define solutions able to identify the building owner requirements for the renovation process. This fact leads to the utilisation of simulation and calculation tools, where a detailed and interlinked design selections can be compiled back to the level of owner's requirements. In addition, this leads also to the need of more collaborative teamwork between the designers, because of the complex relations between the technical details and the owner's requirements[41].

In this context, designers face the challenge not only to predict the building performance (internal temperatures, protection from the climate, etc.) but also to establish a degree of interaction between the occupant and the building itself.[42] Such interaction is intrinsecally hard to be evaluated, and innovation in buildings (such as smart energy technologies, innovative materials as well as innovative design methods like BIM) makes this interaction potentially more complex. These aspects are particularly important in the whole renovation value chain. As buildings are equipped with more adaptive capabilities (solar shading, secure night ventilation, cross ventilation, buffer zones, etc.) the harder part is for designers and other stakeholders to attempt a prediction of building operation and hence of the energy usage exstimation. Here, the accuracy of the data gathering of the existing building and digital means and design methods appears as crucial ones in the renovation value chain.

Contractors and subcontractors

The contractor is responsible for the construction works and coordinates subcontractors during the project implementation phases. The needs and requirements of contractors and subcontractors are mainly related to a clear understanding of the work schedule and interventions, as well as to communicate with all the actors involved.

In fact, a renovation contractor is responsible for obtaining all the necessary permits and licenses from the relevant authorities. In this sense, they have to carry out extensive researches to find out any laws and regulations related to building renovation process. Issues related to budgeting and costs of works are another important role for the contractor, these aspects are mainly related to the need for clearer design indications. In fact, establishing the

[41] BIM4EEB, D2.2 List of Designers' Needs and Requirements for BIM-Based Renovation Processes, available at: https://www.bim4eeb-project.eu/media/doc/D2.2.pdf

[42] BUILDUP "Building operation: the elusive alignment of research, design and occupants", available at: https://www.buildup.eu/en/node/57424

cost of the renovation, tools, and materials is a primary responsibility of the contractor.[43]

Public bodies and administration

Local and public authorities have to supervise renovation projects in order to monitor the adherence to the existing legislative framework as well as to regulations, standards and policies. They need a clear vision on the project and the entire renovation process and access to relevant documentation as well as to have a direct communication with all the involved parties, particularly with the main contractor.
At the same time, public authorities are intended to support and facilitate renovation through existing EU Instruments at the local and regional level in the light of the latest European objectives[44].

Industrials

Material and technology suppliers have the role of providing the materials and technical solutions to be adopted by the contractors and subcontractors in the renovation project.
According to Hasim et al. (2018) [45], an effective and efficient materials procurement system should be created for all construction projects. Potential material yields leads to major delays in construction projects. Therefore, the procurement process of the material needs to be well implemented by improving the procurement process to avoid the delay of supply.
The materials management functions in the construction industry are often performed on a fragmented basis with minimal communication and no clearly established responsibilities among the parties involved.
For these reasons, the authors suggest that a new approach for material management is needed, finding alternative ways to measure and report costs and other data and sharing information for materials and equipment traceability, effective collaboration among involved parties and integration of requests by customers. These elements correspond to the need of the stakeholders category hereby analysed.

Other players included in the industrial category are the ESCO companies. The ESCOs are energy service companies, their main requirements and needs are related to the possibility to have a detailed understanding of the project, including adopted technologies and measures and expected energy saving and performances, in order to be able to provide the best energy contract case by case[46].

Others

Other stakeholders involved in the renovation value chain, hereby classified in the category "Other" include third parties such as Software developer or external consultants, external certification bodies, funders and financial entities and other entities, interested in renovation for education and training purposes or services.

According to the above reported aspects, key requirements and needs for each of the stakeholders categories have been listed in the following Table 4-2.

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[43] Frödell, M. (2011), "Criteria for achieving efficient contractor-supplier relations", Engineering, Construction and Architectural Management, Vol. 18 No. 4, pp. 381-393, available at: https://doi.org/10.1108/09699981111145826

[44] European Union and the Committee of the Regions, Renovation wave and local and regional authorities: policy and tools to build capacity and finance projects, 2020, available at: https://cor.europa.eu/en/engage/studies/Documents/Renovation%20wave%20and%20local%20and%20regional%20authorities%20-policy%20and%20tools%20to%20build%20capacity%20and%20finance%20projects/Renovation%20Wave_Study.pdf

[45] : AIP Conference Proceedings 2020, 020049 (2018); https://doi.org/10.1063/1.5062675 Published Online: 05 October 2018

[46] https://www.iea.org/reports/energy-service-companies-escos-2/esco-contracts

In line with the list reported in the previous chapter for Building owners, residents and occupants, the list includes three different categories of key requirements and needs, namely “Health, comfort and safety”(HS), “Environmental”(EN) and “Optimized economics”(OE). Moreover, an additional category of “General” (GE) requirements was added to cover a wider spectrum of aspects for these stakeholders’ categories.
To facilitate comparison, the category of building owners, residents and occupants is included in the table.

Table 4-2. Key requirements and Needs of Stakeholders

Stakeholders categories								
Key Requirements and Needs			**Designers**	**Contractors and subcontractors**	**Building owners, residents and occupants**	**Public bodies and administrations**	**Industrials**	**Others**
Health and Comfort and Safety	R-HS-01	Aesthetics (Building Aesthetics, Landscape Aesthetics, Aesthetical environment)			X	X		X
	R-HS-02	Air infiltration rate (Building Air tightness, Systems and HVAC airtightness)			X			
	R-HS-03	Indoor Air quality improvement (Mechanical ventilation, Low-emitting materials, Indoor chemical & pollutant source control, Thermal Comfort improvement, Under cooled periods, Over heated periods, Operative Temperature, Humidity, Adaptive comfort approach, Moisture Comfort improvement)			X			
	R-HS-04	Thermal Comfort improvement (Under cooled periods, Over heated periods, Operative Temperature, Humidity, Adaptive comfort approach, Moisture Comfort improvement)			X			
	R-HS-05	Acoustic performance improvement (Acoustic quality)			X			
	R-HS-06	Daylight and views improvement (Illumination levels, % of space with natural light and views, Glare control)			X			
	R-HS-07	Ergonomic Workplace improvement			X	X		X
	R-HS-08	No need for the resident to leave the building during the works			X			
	R-HS-09	Adaptation to changes in comfort expectations and in occupancy trends (such as teleworking, co-working, and home-sharing)			X			

Stakeholders categories								
Key Requirements and Needs			**Designers**	**Contractors and subcontractors**	**Building owners, residents and occupants**	**Public bodies and administrations**	**Industrials**	**Others**
	R-HS-10	Building Safety (Earthquake resistance, Tornado resistance, Flood resistance, Fire safety, hazardous material elimination, Electrical safety, Slip and trip protection)			X			
Environmental	R-EN-01	Energy Consumption			X	X		X
	R-EN-02	Energy delivery performance			X			
	R-EN-03	Energy uses disaggregation in conditioned space			X			
	R-EN-04	Energy uses disaggregation in not conditioned space			X			
	R-EN-05	Total CO_2 emission /reduction			X			
	R-EN-06	Other pollutant emissions reduction (NOx, SOx & particulate matter emissions)			X			
	R-EN-07	Share of energy sources (Solid energy fuels, LNG, fuel, renewable energy source)			X			
	R-EN-08	Eco labelling (LEED, BREEAM, CASBEE...) of the building after renovation			X			X
Optimized Economics	R-OE-01	Technology R&D Cost		X	X			
	R-OE-02	Labor Cost		X	X			
	R-OE-03	Financing Cost		X	X			
	R-OE-04	Technology Application Cost		X	X			
	R-OE-05	Technology Designing Cost		X	X			
	R-OE-06	Technology Maintenance Cost		X	X			
	R-OE-07	Facility Management Cost		X	X			
	R-OE-08	Space & Infrastructure Costs		X	X			
	R-OE-09	People & Organization Costs		X	X			
	R-OE-10	Outdoors Costs		X	X			
	R-OE-11	Cleaning Costs		X	X			
	R-OE-12	Workplace Costs		X	X			

Stakeholders categories								
Key Requirements and Needs			**Designers**	**Contractors and subcontractors**	**Building owners, residents and occupants**	**Public bodies and administrations**	**Industrials**	**Others**
	R-OE-13	Primary activities specific Costs		X	X			
	R-OE-14	Logistics Costs		X	X			
	R-OE-15	Business support Costs		X	X			
	R-OE-16	Reduction of Energy Consumption		X	X			
	R-OE-17	Length of Payback Period		X	X			
	R-OE-18	Energy-Saving Consciousness of Occupants		X	X			
	R-OE-19	Level of Marketization of Technology and Product- Marketability		X	X			
	R-OE-20	Level of Massive Development of Technology and Product		X	X			
	R-OE-21	Longer building lifetime		X	X	X		X
	R-OE-22	Increase in the building value		X	X			X
	R-OE-23	Access to financial subsidies				X		X
General	R-GE-01	Reduction of project development time	X	X				
	R-GE-02	Maintenance cost reduction				X		X
	R-GE-03	Resident's comfort improvement				X		
	R-GE-04	CO2 and other pollutant emissions reduction				X		X
	R-GE-05	Accuracy of the data gathering of the existing building	X	X		X	X	X
	R-GE-06	Organization of the documentation	X	X		X	X	X
	R-GE-07	Improvement of the company's reputation	X	X		X	X	X
	R-GE-08	Easy collaboration with other stakeholders				X		X
	R-GE-09	Easy collaboration with the client	X	X				
	R-GE-10	Easy collaboration with suppliers		X				
	R-GE-11	Easy interaction with the contractor					X	
	R-GE-12	Easy interaction with the designer					X	
	R-GE-13	Easy visualization of the solution	X	X		X	X	X

Stakeholders categories								
Key Requirements and Needs			**Designers**	**Contractors and subcontractors**	**Building owners, residents and occupants**	**Public bodies and administrations**	**Industrials**	**Others**
	R-GE-14	Integration of requests from residents	X	X		X	X	X
	R-GE-15	Compliant management	X	X		X	X	X
	R-GE-16	Justification of the Decisions Making	X	X		X		X
	R-GE-17	Validation of the standards compliance in the project	X	X			X	X
	R-GE-18	Reduction of the visits to site	X	X				
	R-GE-19	Reduction of number of workers on site		X		X		
	R-GE-20	Reduction of accidents on site		X				X
	R-GE-21	Reduction of unforeseen event on site		X		X		X
	R-GE-22	Support to classification and organization of the material on site		X			X	
	R-GE-23	Support to the control quality		X		X		X
	R-GE-24	Reduction of delivery time				X	X	X
	R-GE-25	Reduction of construction time					X	
	R-GE-26	Create best practices	X					
	R-GE-27	Easy replication	X	X				X
	R-GE-28	Prediction accuracy for the building performance (internal temperatures, protection from the climate, etc.)	X					X
	R-GE-29	Establishment a degree of interaction between the occupant and the building	X					X

4.1.2 Review on Technical, Financial, and Social Barriers and Challenges in Deep Building Renovation

4.1.2.1 Main Barriers Encountered in EU Deep Renovation

A detailed review of 31 EU funded projects[47] that deal with state-of-the art deep renovations, running from 2008 up to 2020 was performed by D'Oca et al.(2018) in their article "Technical, Financial, and Social Barriers and Challenges in Deep Building Renovation: Integration of Lessons Learned from the H2020 Cluster Projects" [48].
The study has indicated that EU projects have tackled the main barriers of deep-renovation through the search for innovative technological solutions to overcome the obstacles that are currently present in the market of energy requalification.
A cross-check with other sources identified in the framework of this analysis, namely other analysis of the renovation sector developed in the framework of EU funded projects (please refer to Table 2-1 for complete list) showed strong similarities between the analyses and provided the evidence of the robustness of the hereby reported categorization.
Main barriers (B) found in the deep renovation processes have been summarised in three categories, namely Technical (TC), Social (SO) and Financial (FI) barriers, as reported in the following Table 4-3.

Table 4-3. Technical, Social and Financial Barriers

#	Technical Barriers
B-TC-01	Lack of consistent and standardized solutions or integrated solutions to comply with new and different building standards requirements on energy saving
B-TC-02	Lack of skilled and experienced resources (workers) to carry out the work
B-TC-03	Safety/seismic risk connected with the deep renovation processes (damages can be done to the homes while retrofitting or unsure perception of the current safety of the existing buildings
B-TC-04	End users' and owners' lack of technical expertise and trust in effective energy renovation savings
#	Social Barriers
B-SO-01	Decision-making processes that are long and complex, especially in cases of multi-owner houses (condominiums)
B-SO-02	Lack of consensus, understanding, and support from the inhabitants that often hinder the effective approval of the interventions
B-SO-03	Problem of disturbance during site works and/or relocation (in case owners/users need to leave their homes during the process)

[47] A2PBEER (GA n.60960), ABRACADABRA (GA n.696126), ADAPTIWALL (GA n.608808), BERTIM (GA n.636984), BRESAER (GA n.637186), BuildHEAT (GA n.680658), CETIEB (GA n.285623), E2VENT (GA n.637261), EASEE (GA n.285540), EENSULATE (GA n.723868), HERB (GA n.314283), IMPRESS (GA n.636717), INSITER (GA n.636063), iNSPiRe (GA n.691440), MeeFS (GA n.285411), MORE-CONNECT (GA n.633477), NewTREND (GA n.680474), OptEEmal (GA n.680676), P2Endure (GA n.732391), REFURB (GA n.649865), REnnovates (GA n.680603), RetroKit (GA n.314229), RE4 (GA n.723583), VEEP (GA n.723582), TransitionZero (GA n.696186), 4RinEU (GA n.723829), IEE ZEBRA 2020, IEE NeZeR, smarTES (ERA-Net WoodWisdom-Net 2004-2008)
[48] D'Oca S., Ferrante A., Ferrer C., Pernetti R., Gralka A., Sebastian R. and Veld P., 2018., Technical, Financial, and Social Barriers and Challenges in Deep Building Renovation: Integration of Lessons Learned from the H2020 Cluster Projects. Buildings

B-SO-04	Low awareness about energy efficiency and non-energy benefits of renovation
B-SO-05	Lack of dialogue between the different stakeholders
#	Financial Barriers
B-FI-01	High up-front costs and owners reluctant to borrow funds for energy renovation purposes
B-FI-02	Long pay-back times of retrofitting interventions
B-FI-03	Lack of confidence of the potential investors
B-FI-04	Insufficient and instable available funding
B-FI-05	Lack of attractive financing for homeowners with low to medium incomes who are usually not eligible for regular bank loans
B-FI-06	Existing financial tools are insufficient and unattractive

Financial aspects are among the highest barriers for building owners and co-owners when it comes to renovations. Payback and up-front costs are crucial in this context. In addition, the lack of funding opportunities and/or inability to secure finance on acceptable terms is generally one of the most cited barriers to investing in energy efficiency measures.
The barriers identified, highlight a strong need to create a demand both from the market and the final users to strengthen investors' confidence and accelerate the market uptake of deep renovation solutions and technologies.
The barriers identified by the authors will be considered as a preliminary reference for the scope of this document and will provide a basis for stakeholders' consultation via the questionnaire. The consultation of stakeholders will provide further information and indication on the relative importance of each of the barriers, according to experts' opinion, role and experience. The analysis will be further detailed along with the project, particularly focusing on the barriers identified within the RINNO project demonstration phase.

4.1.2.2 Review of Challenges

Following the review of barriers, the present section of the document analyses the challenges identified by D'Oca et al. in their systematic review of EU project targeting deep renovation[48]. In line with identified barriers, three main categories of challenges are identified, namely Technical (TC), Social (SO) and Financial (FI) challenges (C).

Several EU funded projects recently have focused on the investigation of technological solutions for deep renovation[47]. In particular, the focus is usually on integrated packages aimed at improving performance while reducing the time and complexity of the interventions, combining a set of renovation measures for the envelope and the HVAC system.

In the context of innovative deep renovation practices, it is more urgent to understand what is relevant when it comes to technological aspects for end users, including how property owners perceive technological changes and how they assess their benefits and potential disadvantages.
The complete list of identified Challenges is reported in the following Table 4-4.

Table 4-4. Technical, Social and Financial Challenges

#	Technical Challenges
C-TC-01	Integrated technical solution packages with aiming improving performance
C-TC-02	Reducing time and complexity of the interventions

C-TC-03	Delivering a reliable and cost-effective renovation process
C-TC-04	Environmentally friendly renovation process
C-TC-05	Less disruption to the residents than the conventional renovation practices
C-TC-06	Easy to install (plug-n-play) technologies
C-TC-07	Increasing the levels of energy efficiency and renewable energy production
C-TC-08	Standardized solutions that can be easily applied to achieve compliance to different building standards
#	Social Challenges
C-SO-01	Lack of education and confidence in construction professionals
C-SO-02	Consumer acceptance of new technologies and innovative renovation solutions
C-SO-03	Knowledge of available solutions and customizability
C-SO-04	Disruption factor (refers to all the troubles linked to refurbishment work for the occupant)
C-SO-05	Decision-making in condominiums
#	Financial Challenges
C-FI-01	Return of investment
C-FI-02	Funding schemes

The analysis and identification of challenges will be further detailed along the project, particularly focusing on those targeted by the RINNO technology packages and solutions. The list of challenges of the previous table were presented in the stakeholders questionnaire in order to receive feedbacks and collect relevant insights on the subject from involved experts, with the ultimate goal of identifying a ranking of relative importance.

4.2 Analysis of questionnaire responses

In the following section it has been carried out the analysis of the responses to the online questionnaire; the chapter is divided into three sections:

- General information, profile and renovation experience of the questionnaire participants;
- Analysis of the key requirements and needs of stakeholders in the renovation value chain with a particular focus on the building owners category;
- Analysis of the main barriers and challenges in the renovation projects identified by the participants.

As mentioned in section 2.3, the online public questionnaire has been shared to the RINNO consortium members, RINNO extended stakeholders' community, as well as other recipients involved in the renovation value chain. The questionnaire has been distributed to the target groups, by the members of RINNO consortium through direct emails pointing the partners' networks of contacts across Europe and even non-European countries.

From the around total of 82 questionnarie contributions, 64 of them were completed providing valid outputs which are presented and described within the next sections.

4.2.1 General information, profile of stakeholders and overview of renovation process

In order to identify the profile of the questionnaire participants and their relationship with renovation process, the first part of the questionnaire has been focused on general aspects to reach a wider general knowledge of the building renovation.

The first question is about the core business of the organization of the participants; this question is aimed at identify which sector of the renovation process is the most present within this questionnaire. The participation on the questionnaire is not homogenous with the profile of the respondents and three type of organizations represent the 55% of the total, with 21% of the questionnaires completed by research and development institution, 17% by prodiver of services, and 17% by building owners. Of the total, only 34% is not directly involved in the renovation process, the others declared a former experience or a direct involvement in the building renovation process.

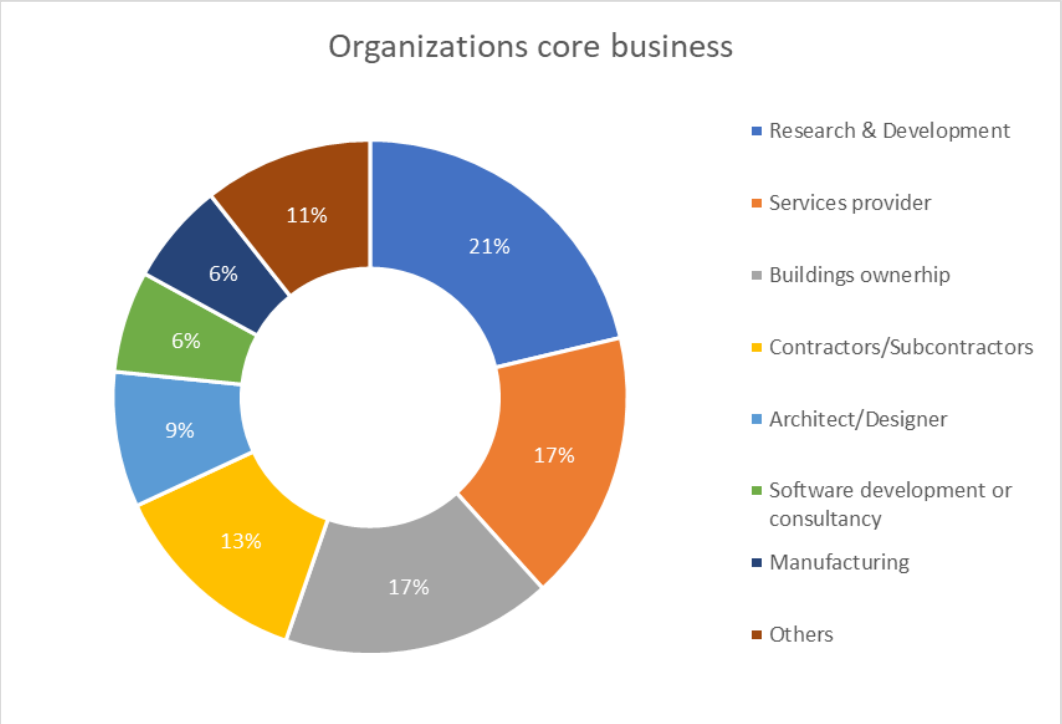


Figure 4.1. Organitations core business of the questionnaire participants

According to the participation on the questionnarie, the most common building typologies involved in the renovation is residential building (46%), followed by officies (15%) and industrial buildings (10%)(Figure 4.2). Focusing on the residential building answer, according to the questionnaire, the most renovated are the apartments block/tower and the single family houses Figure 4.3.

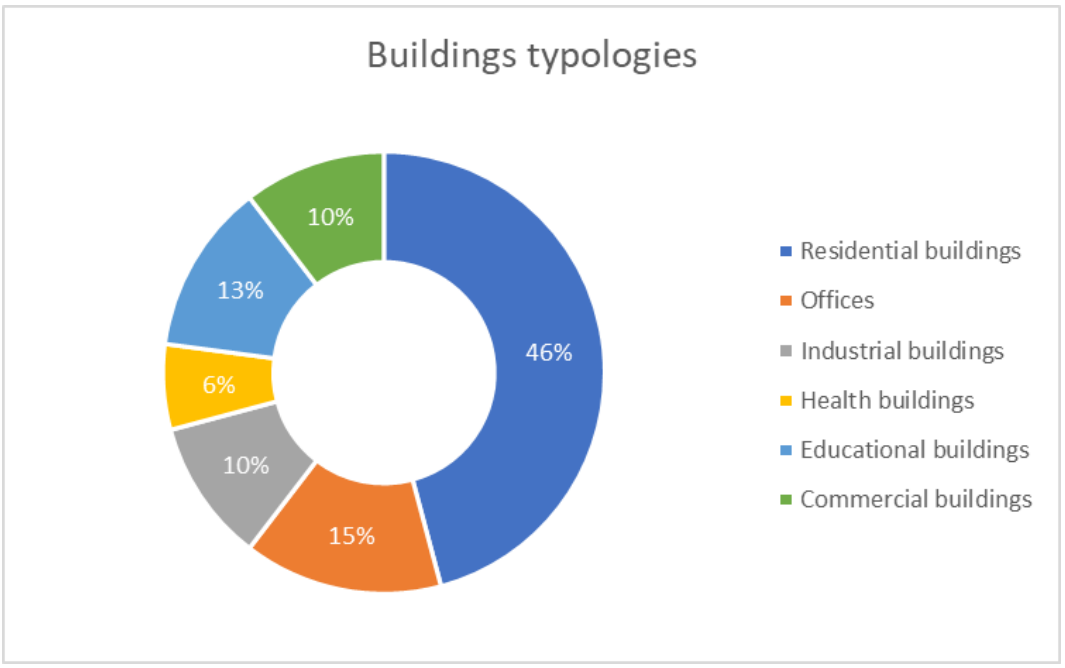


Figure 4.2. Typologies of buildings in the renovation process

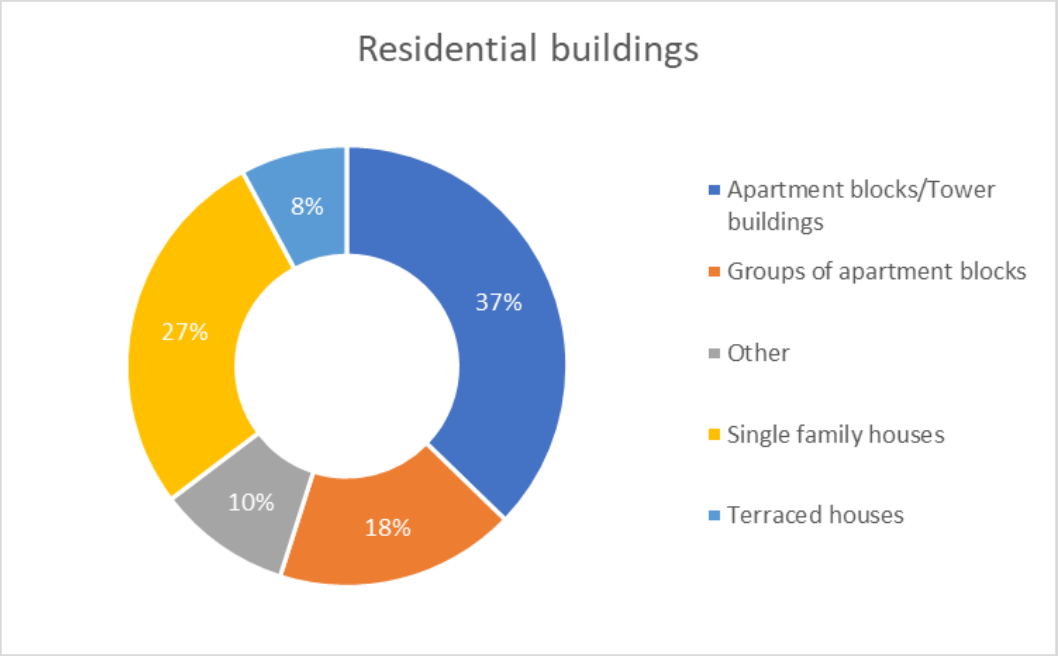


Figure 4.3. Fcous on the residential buildings in the renovation process

Concerning the renovation project phases Figure 4.4, the paticipants are mainly involved into Revovation Technical aspects, Strategic definition and Information gathering and audit.

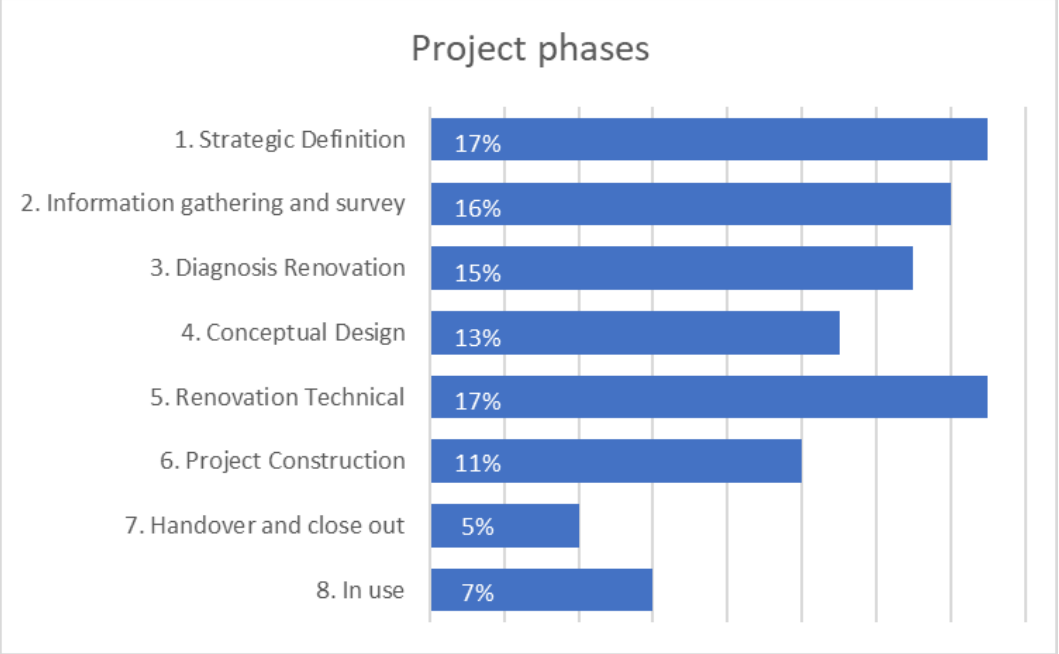


Figure 4.4. Building renovation process phases

As the Figure 4.5 reports, the most developed renovation work typologies are service improvement (HVAC, RES, Electricity, Plumbing and Sewage, Fire security…) (32%), followed by interventions in the envelope (Framing and glazing replacement, Roof retrofitting…) (21%) and structural retrofitting (Column & Beams, Slabs, Load bearing Walls…) (12%).

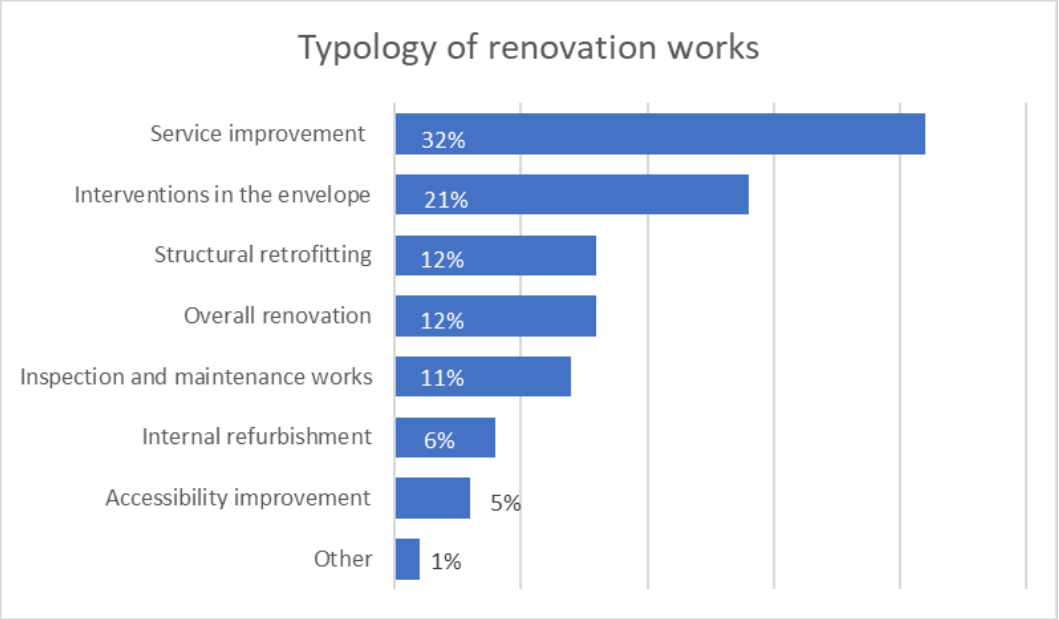


Figure 4.5. Renovation work typologies

The phases of the renovation process which face more difficulties areproject construction, (22%), renovation technical (21%) and information gathering and audit (18%). Figure 4.6.

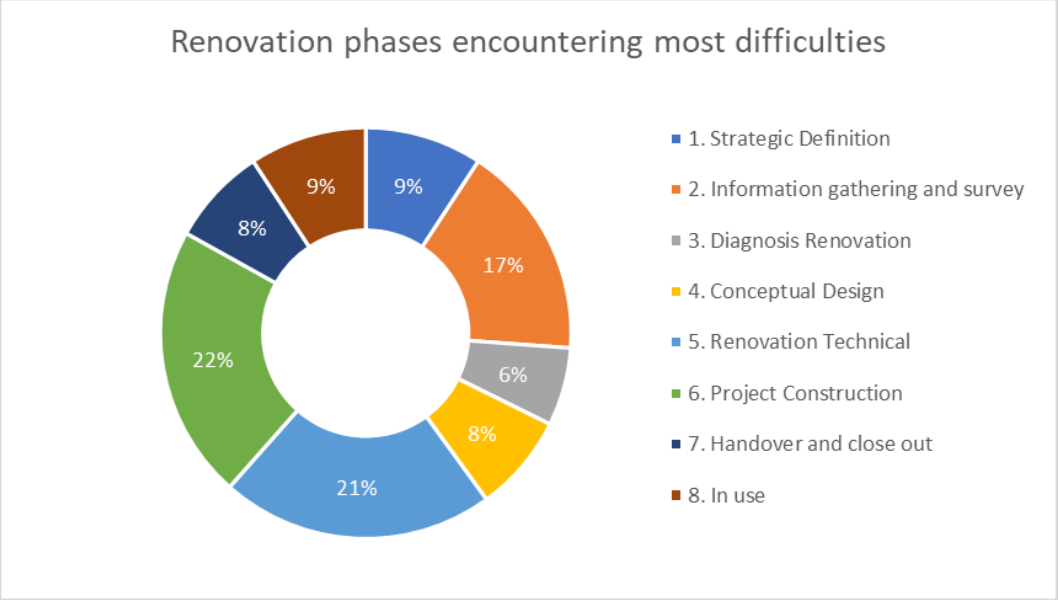


Figure 4.6. Phases of the renovation process where higher difficulties are present

4.2.2 Identification of the requirements and needs in the renovation process

The objective of this section is to map different use cases in the renovation process with regard to phases of the process, stakeholders involved and typology of works as well as the main requirements, needs and benefits expected at the end of the process, according to the role in the value chain of the participants.

Moreover, the analysis is aimed at assessing the factors in a renovation process which have more relevance to the stakeholders according to the role in the value chain in the renovation process. In this part of the questionnaire, have been asked to the stakeholders to assess a score on scale from 1 to 5 to define the importance of the key requirements and needs. (1: Not Important, 2: Slightly Important, 3: Moderately Important, 4: Important, 5: Very Important).

The first question of the section is aimed to understand the main roles of respondents in the renovation process. The participation on the questionnaire is not homogenous, designers represent the 34% of the total, figures involved in the industrial sector (suppliers, manufacturer etc..) are the 24% and the building owners are the 22% of the questionnaires completed.

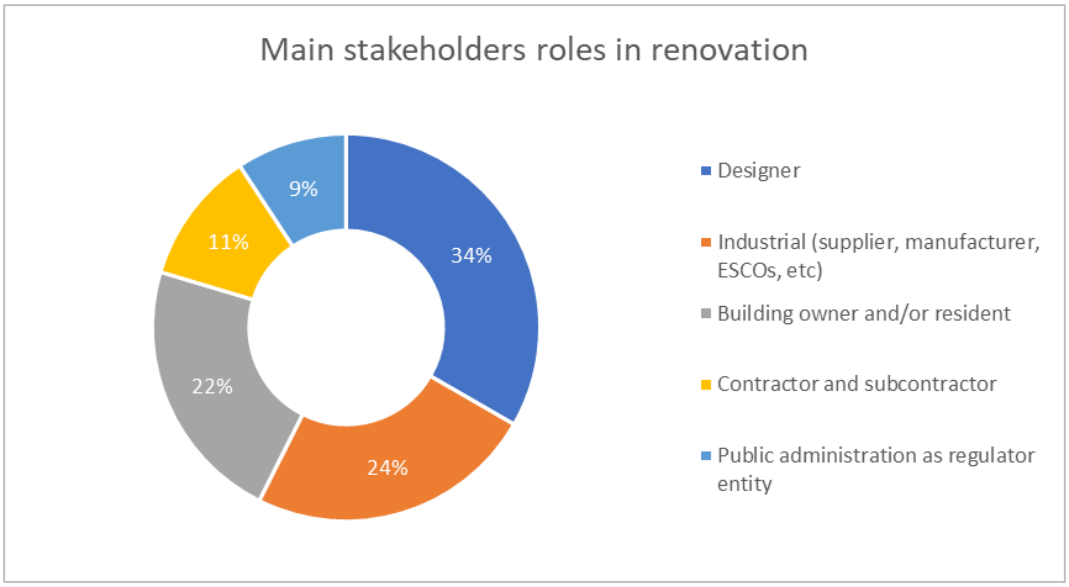


Figure 4.7. Main roles of stakeholder in the renovation process

For each category, a deep analsys on the answers has been performed and it is presented within the following sections.

Designers Stakeholder Category Requirements and Needs

Designers as part of stakeholders have been asked to assess scores to define importance of the following key requirements and needs. For this aim 1-5 scale has been used (1: Not Important, 2: Slightly Important, 3: Moderately Important, 4: Important, 5: Very Important). Average of questionnaire responses are showed in below figure 11.

According to questionnarie analysis, the most important key requirements for designers are the prediction accuracy for the building performance, the cost reduction, the accuracy of the data gathering of existing building and the reduction of project development time.

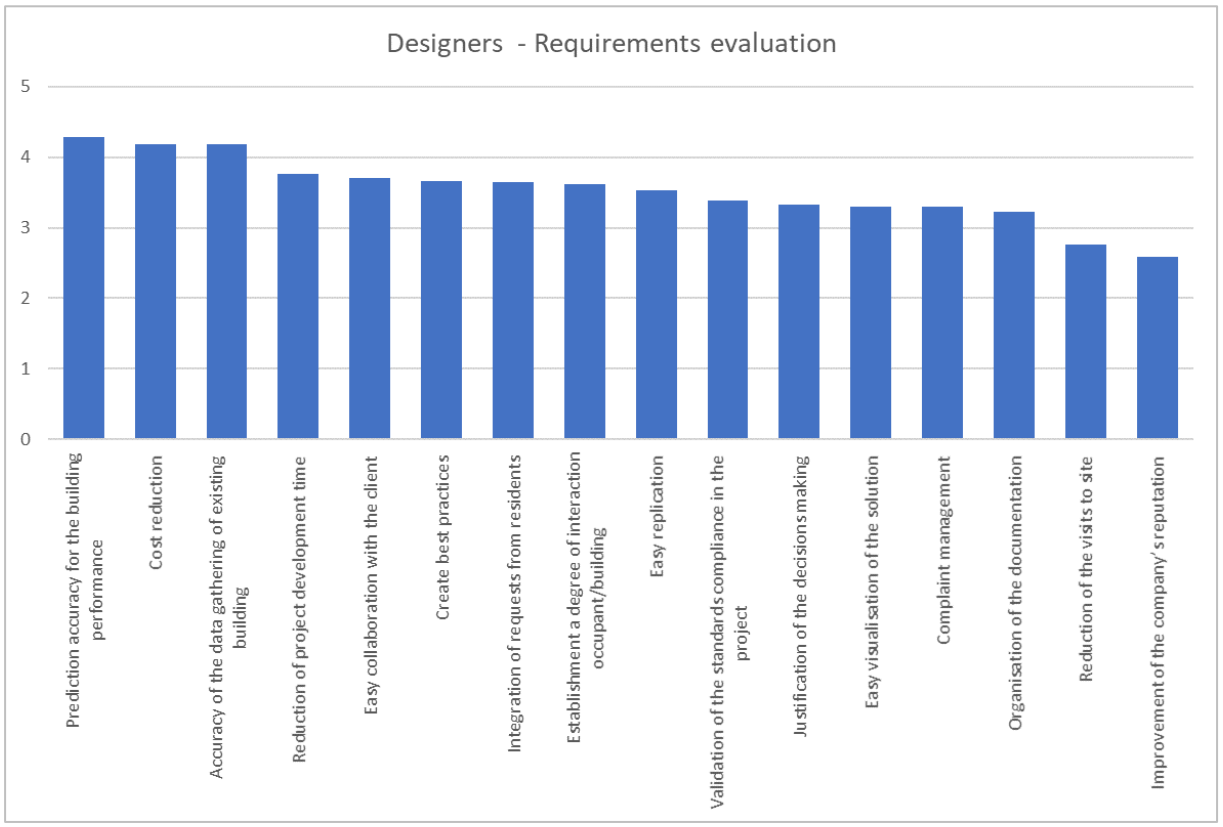


Figure 4.8. Designers / Key Requirements & Needs Importance

Contractors and Subcontractors Stakeholder Category Requirements and Needs

Contractors and subcontractors as part of stakeholders have been asked to assess scores to define importance of the following key requirements and needs. For this aim 1-5 scale has been used (1: Not Important, 2: Slightly Important, 3: Moderately Important, 4: Important, 5: Very Important). Average of questionnaire responses are showed in below Figure 4.9 and Figure 4.10.

According to questionnaire analysis, the most important key requirements for contractors and subcontractors are the reduction accidents on the site, the improvement of the company's reputation, and the reduction of unforeseen event on site.

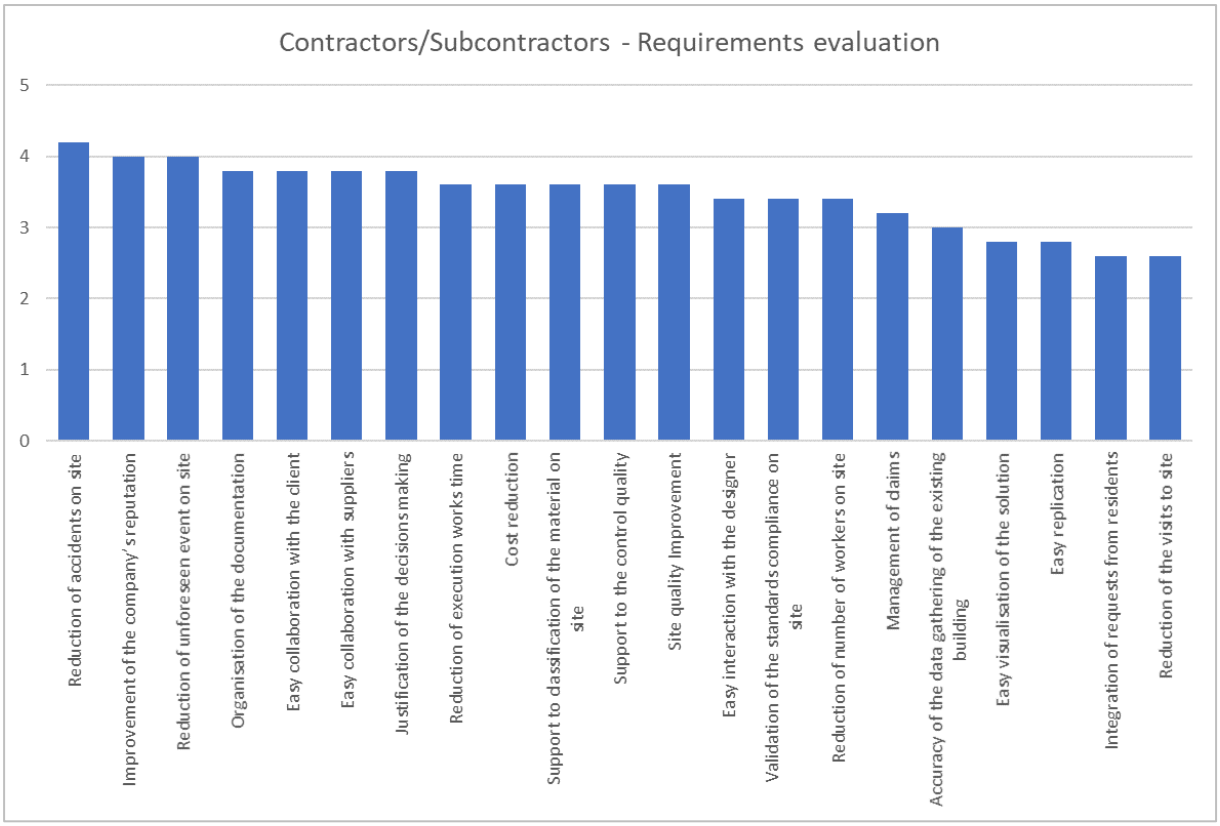


Figure 4.9. Contractor and subcontractor /General Key Requirements and Needs Importance

Concerning the economical aspects, the most relevant requirements are the reduction of energy consumption, the people & organization costs and the workplace costs. Figure 4.10.

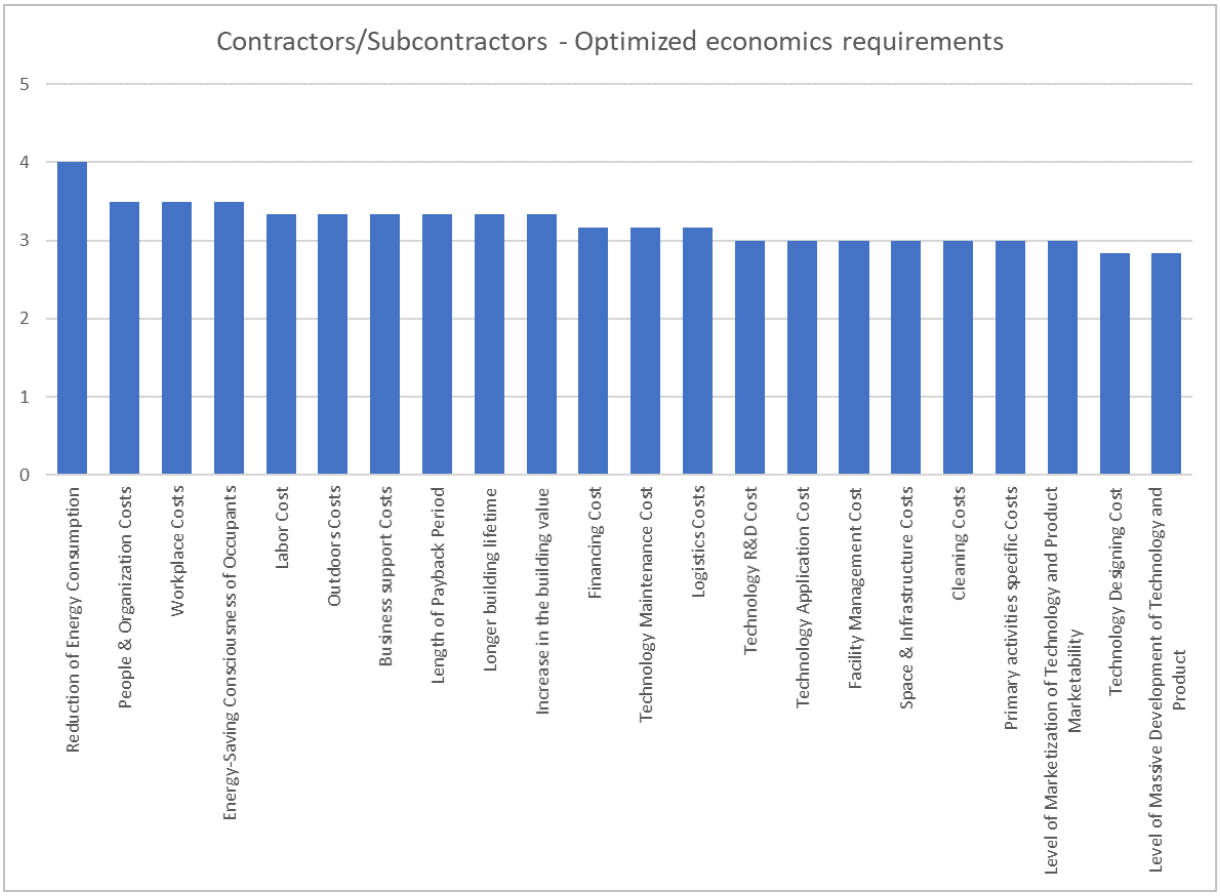


Figure 4.10. Contractor and subcontractor / Optimized Economics Requirements and Needs Importance

Public bodies and administration Stakeholder Category Requirements and Needs

Public bodies and administration as part of stakeholders have been asked to assess scores to define importance of the following key requirements and needs. For this aim 1-5 scale has been used (1: Not Important, 2: Slightly Important, 3: Moderately Important, 4: Important, 5: Very Important). Average of questionnaire responses are showed in the graph below.

According to questionnaire analysis, the most important key requirements for public bodies and administration are energy savings, cost reduction and maintenance costs reduction.

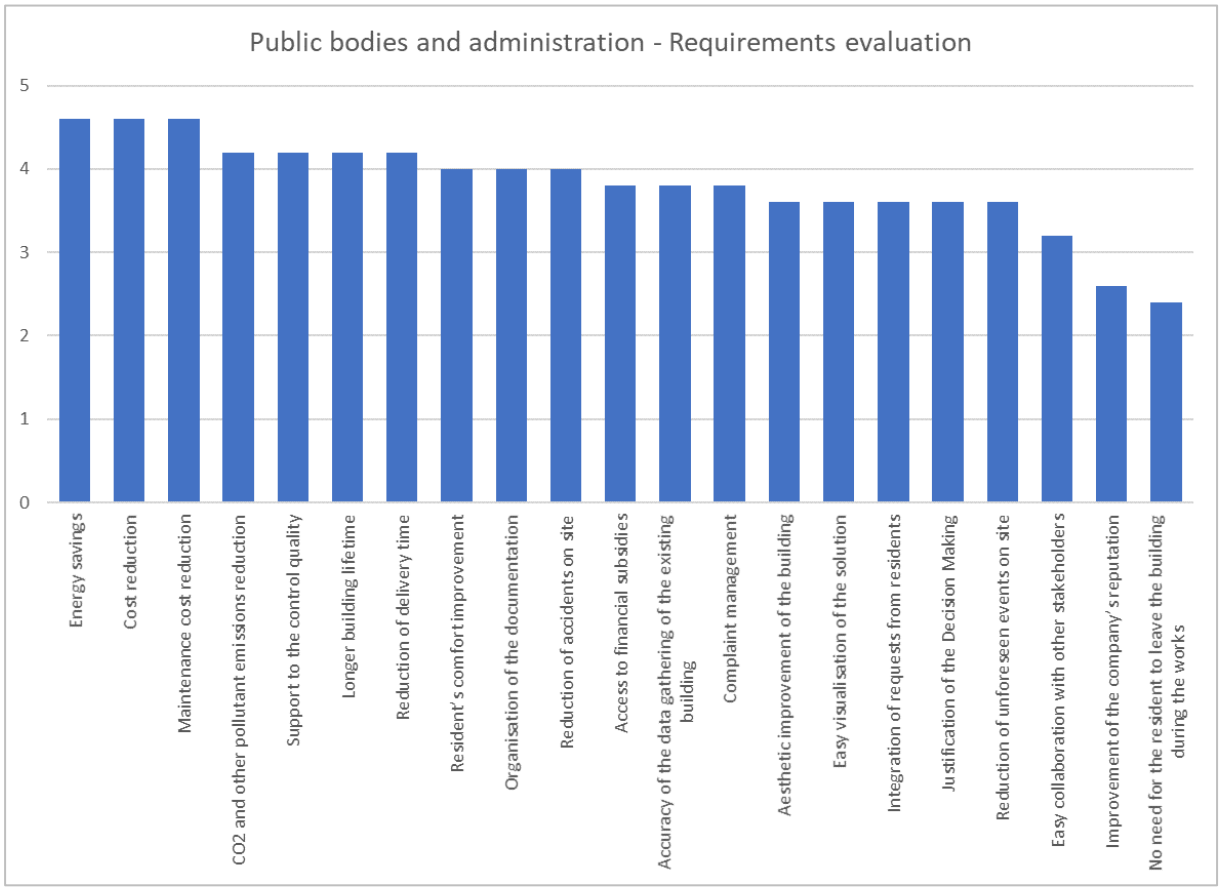


Figure 4.11. Public bodies and administration / Key Requirements & needs Importance

Building Owner and/or Resident Stakeholder Category Requirements and Needs

Building Owner and/or Resident stakeholders as part of stakeholder's category have been asked to assess scores to define importance of the following key requirements and needs. For this aim 1-5 scale has been used (1: Not Important, 2: Slightly Important, 3: Moderately Important, 4: Important, 5: Very Important). Average of questionnaire responses are showed in below Figure 4.12, Figure 4.13, Figure 4.14.

According to questionnaire analysis, the most important key requirements for building owner and/or residents administration are the reduction of energy consumption, the improvement of the thermal and acustic comfort, longer building life time, reduction of total CO_2 and other emissions.

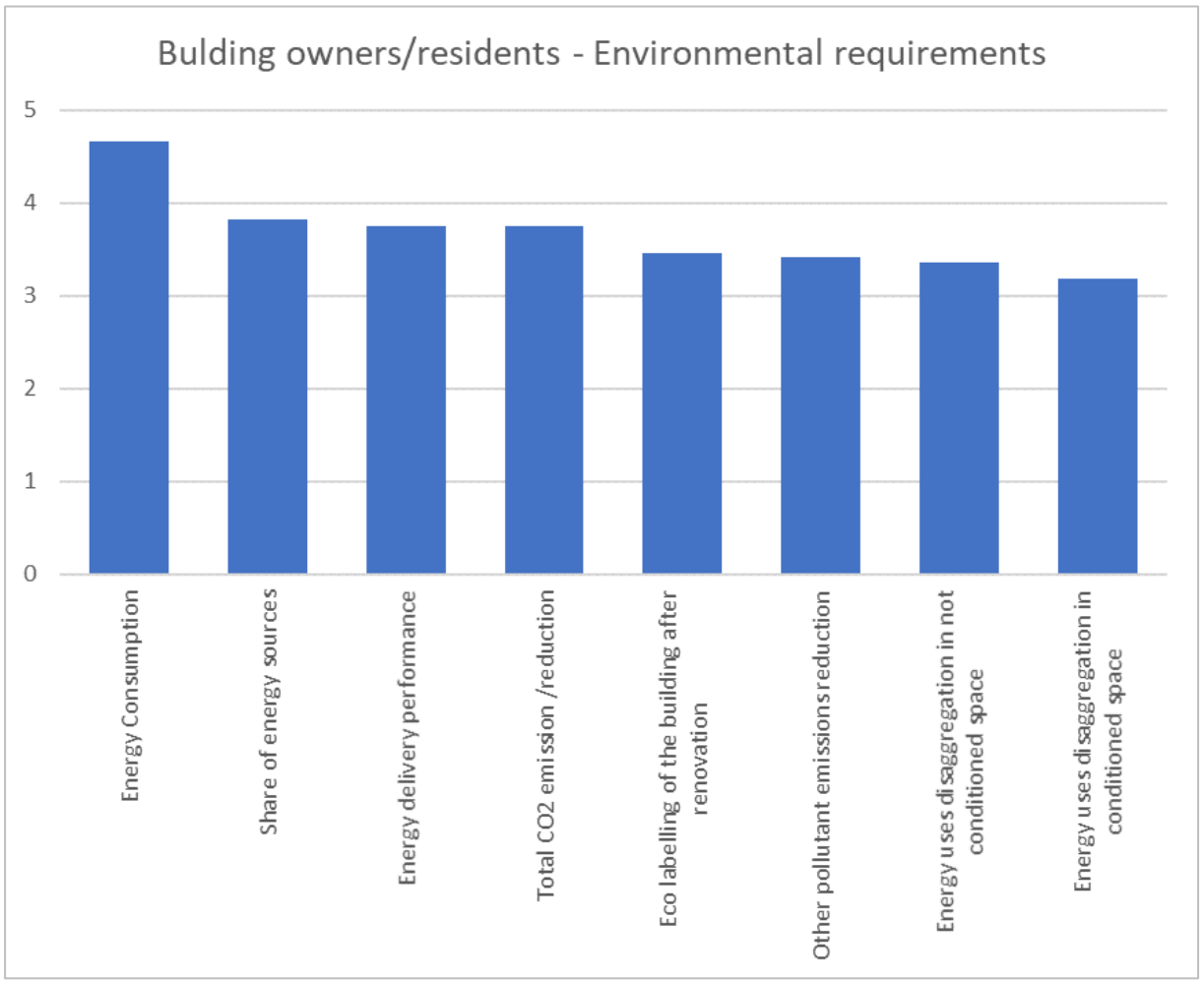


Figure 4.12. Building owner and/or resident / Environmental Requirements

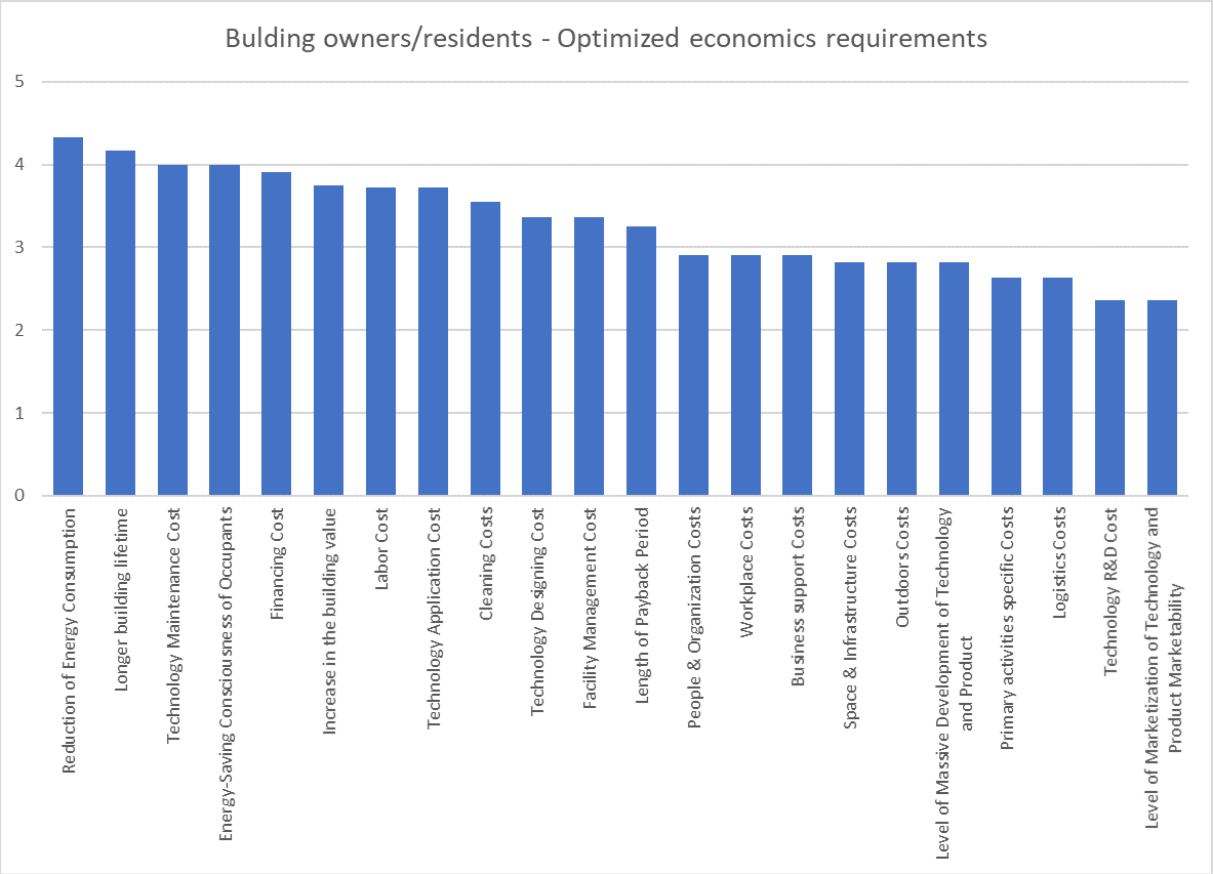


Figure 4.13. Building owner and/or resident / Optimized Economics Requirements

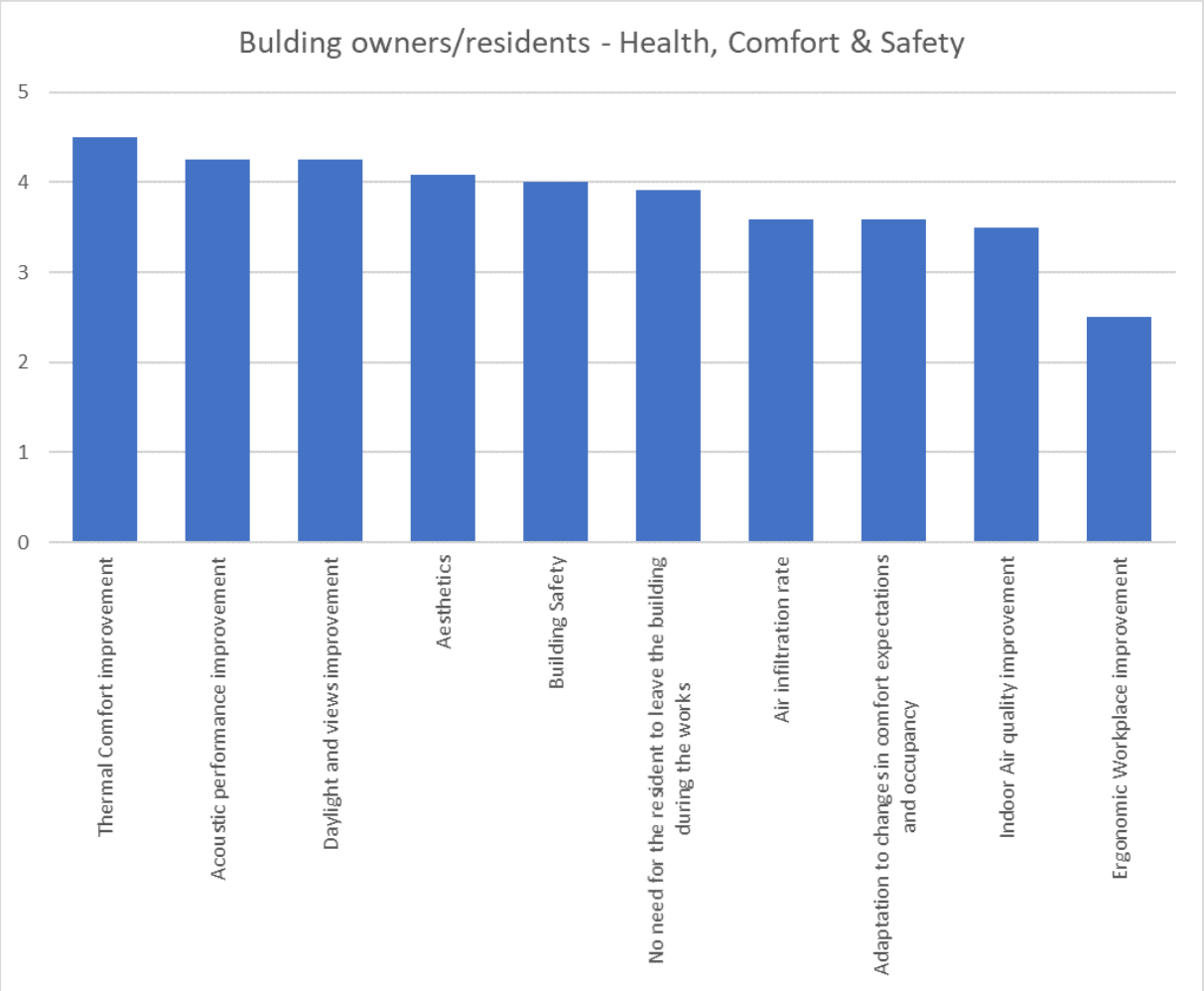


Figure 4.14. Building owner and/or resident / Health, Comfort and Safety Requirements

Industrial Stakeholder Category Requirements and Needs

Industrial stakeholders as part of stakeholder's category have been asked to assess scores to define importance of the following key requirements and needs. For this aim 1-5 scale has been used (1: Not Important, 2: Slightly Important, 3: Moderately Important, 4: Important, 5: Very Important). Average of questionnaire responses are showed in below Figure 4.15.

According to questionnaire analysis, the most important key requirements for industrial stakeholders are the cost reduction, the improvement of the company's reputation, an easy integration with the designers, and the integration requests from residents.

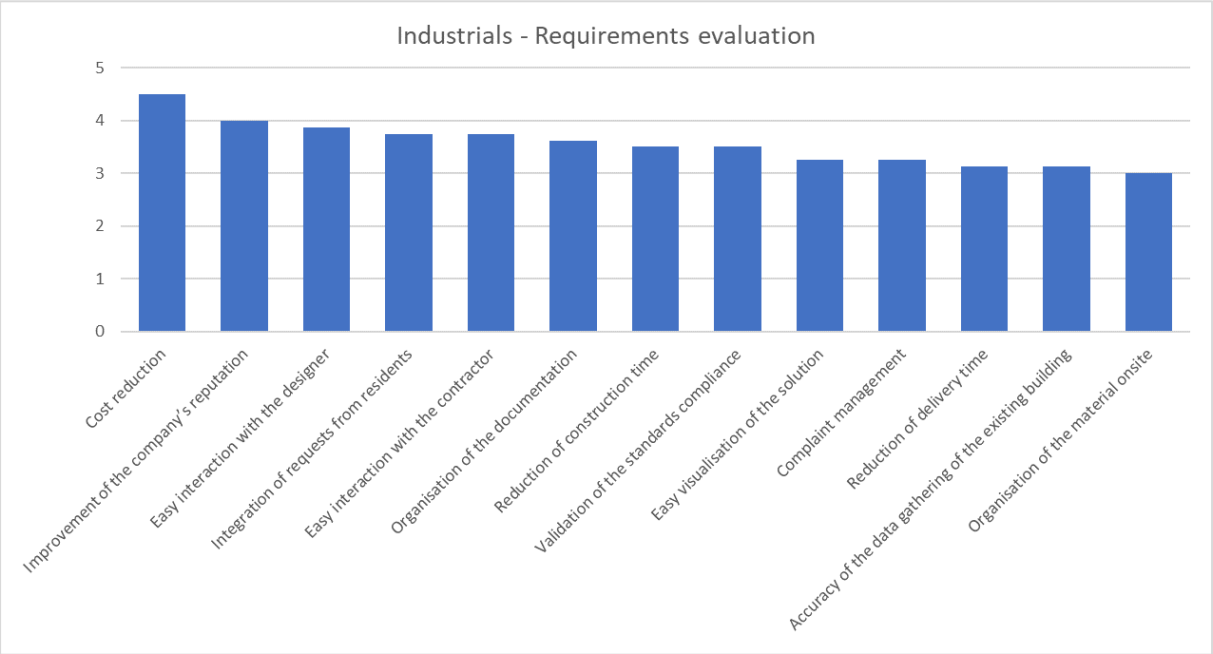


Figure 4.15. Industrial / Key Requirements & Needs Importance

Others Stakeholder Category Requirements and Needs

Others stakeholders as part of stakeholder's category have been asked to assess scores to define importance of the following key requirements and needs. For this aim 1-5 scale has been used (1: Not Important, 2: Slightly Important, 3: Moderately Important, 4: Important, 5: Very Important). Average of questionnaire responses are showed in below Figure 4.16.

According to questionnaire analysis, the most important key requirements for others stakeholders' category are energy savings, cost reduction, access to financial subsidies, maintenance cost reduction, CO_2 and other emissions reduction and reduction of delivery time.

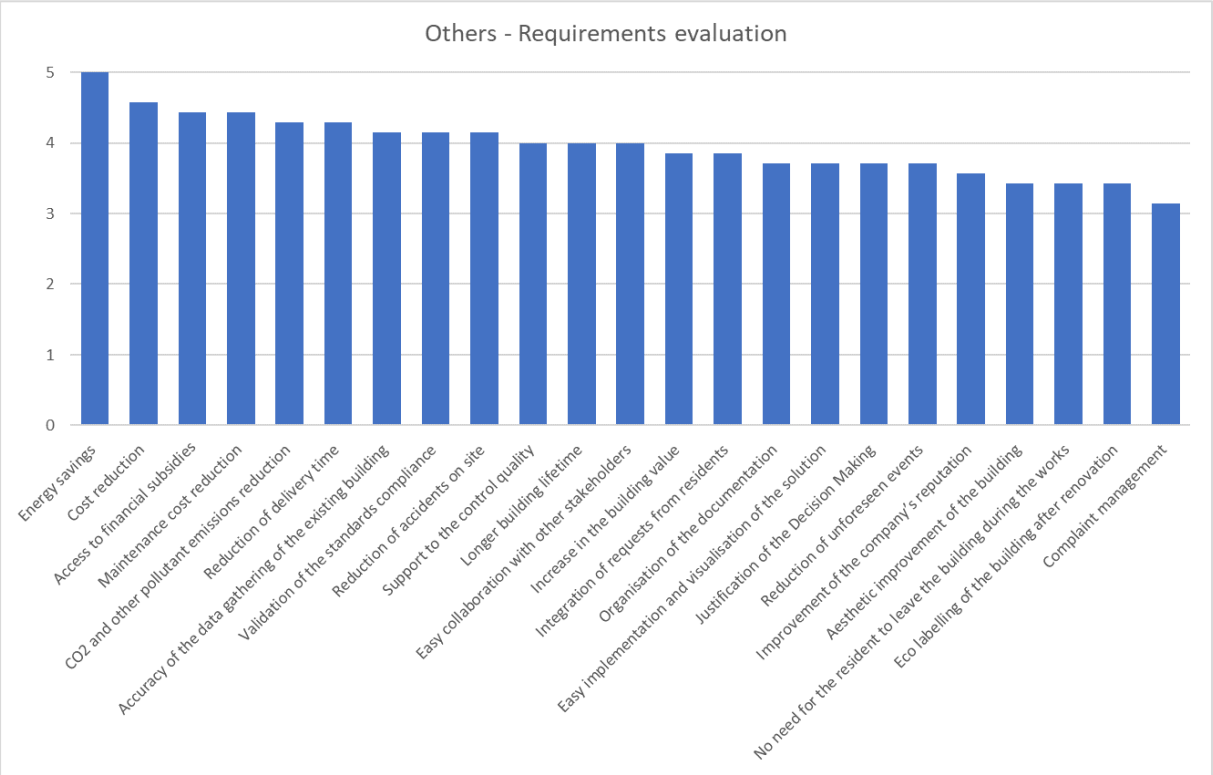


Figure 4.16. Other / Key Requirements & Needs Importance

4.2.3 Identification of Barriers & Challenges in Renovation Process

The objective of this section of the questionnaire is to identify the barriers and challenges in renovation processes and to understand how technologies can meet the demands of the stakeholders as a part of the renovation process.

The project will offer a portfolio of innovative technologies and solutions in order to address the various barriers and challenges faced by the building renovation market, aiming at delivering a reliable and cost-effective renovation process that is attractive to stakeholders, environmentally friendly, and causes less disruption to the residents than the conventional renovation practices.

In this part of the questionnaire, all stakeholders have been asked to specify a score from 1 to 5 to define importance of technical and social barriers & challenges which could give value to their business, according to the impact on it. (1: Not Important, 2: Slightly Important, 3: Moderately Important, 4: Important, 5: Very Important).

Technical Barriers

All stakeholders have been asked to specify scores to define importance of technical barriers and average of questionnaire responses is shown in below Figure 4.17.

Questionnaire analysis has indicated that the most important technical barriers for stakeholders are a lack of technical expertise in energy savings, a lack of consistent and standardized solutions or integrated solutions to comply with new and different building standards requirements on energy savings and lack of skilled workers to carry out the works.

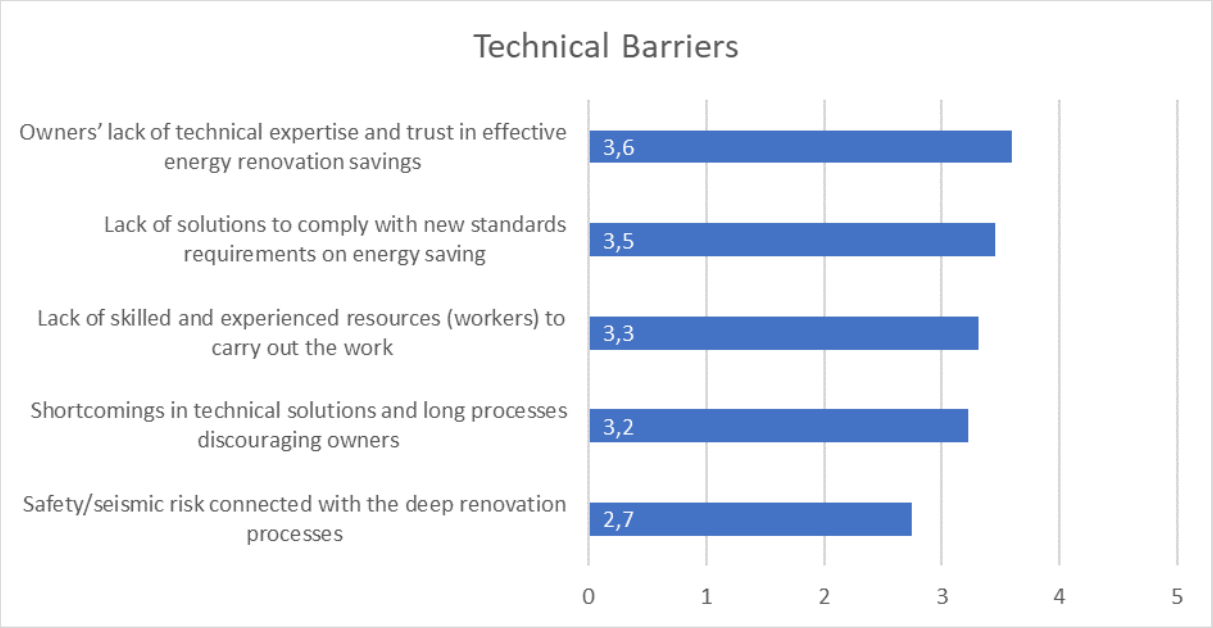


Figure 4.17. Technical Barriers Importance

Social Barriers

All stakeholders have been asked to specify scores to define importance of social barriers and average of questionnaire responses is showed in below Figure 4.18.

Questionnaire analysis has indicated that the most important social barriers for stakeholders are the decision-making processes that are long and complex, especially in cases of multi-owner houses, low awareness about energy efficiency and non-energy benefits of renovation and lack of consensus, understanding and support from inhabitants

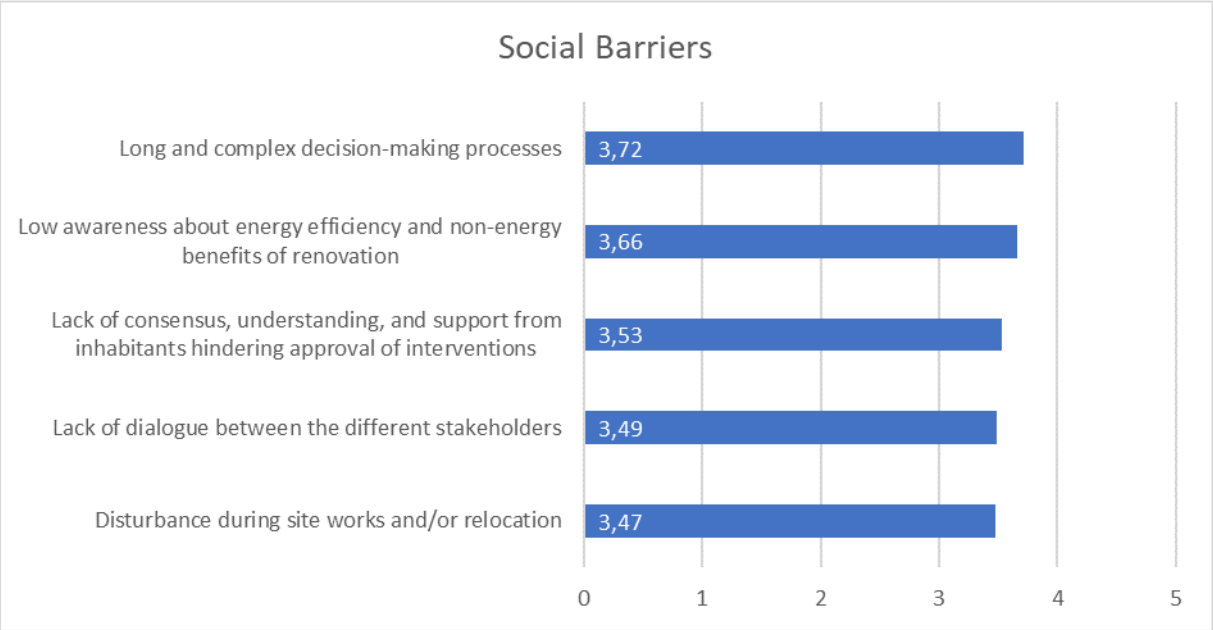


Figure 4.18. Social Barriers Importance

Technical Challenges

All stakeholders have been asked to specify scores to define importance of social barriers and average of questionnaire responses is showed in below Figure 4.19.

Questionnaire analysis has indicated that the most important technical challenges for stakeholders are the increasing levels of energy efficiency and renewable energy production, ensuring a environmentally friendly renovation process, and delivering a reliable and cost-effective renovation process.

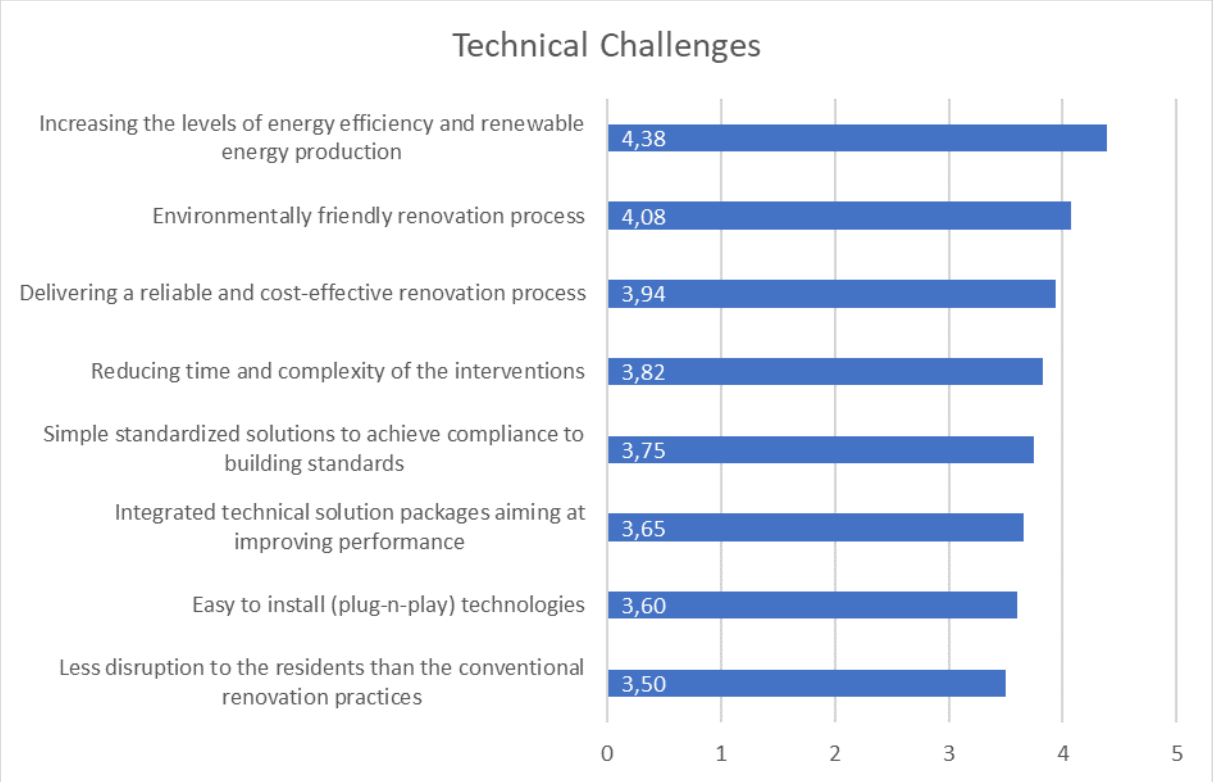


Figure 4.19. Technical Challenges Importance

Social Challenges

All stakeholders have been asked to specify scores to define importance of social barriers and average of questionnaire responses is showed in below Figure 4.20.

Questionnaire analysis has indicated that the most important social challenges for stakeholders are the confidence in construction professionals, the knowledge of available solutions and customizability and consumer acceptance of new technologies and innovative renovation solutions.

Figure 4.20. Social Challenges Importance

4.3 RINNO Key Requirements

In this section, RINNO Key Requirements are selected as a preliminary list for the first phase of the project. The list is based on:

- Analysis of the literature documentation, the review of the most relevant H2020 project and RINNO partners previous experience aimed at identifying the key stakeholders' needs as well as the barriers and challenges they face in relation to the renovation process (Section 4.1)

- In the framework of the RINNO project, an online questionnaire has been launched (see Annex 2). It is aimed at gathering information about the common practices and the main requirements of the stakeholders involved in the whole renovation value chain, the current barriers identified in the renovation processes and how technology could help to overcome them. (Section 4.2).

- Analysis of synergies within RINNO WP1 to define a preliminary building renovation KPIs list for the evaluation of RINNO technologies/solutions performance throughout project evolution from a technical, economic, environmental and social perspective.

RINNO key requirements are described in Table 4-5. The selected key requirements are a preliminary list useful to test the RINNO technologies/solutions during the first 2 years of the project and, before month 24, a fine-tuning revision will be performed, resulting in the final version of the work (Deliverable 1.2 – M24).

The preliminary RINNO requirements analysed within this deliverable have been considered in the selection of KPIs for Deliverable 1.6, in order to take into account the renovation needs and requirements of stakeholders. It is important to note, that the consultation process in Task 1.1 and Task 1.4 is still ongoing and, therefore, the conclusions are still provisional and will be fine-tunned in the final version at the end of the RINNO project. A brief overview of the KPIs considered relevant for the assessment of RINNO solutions is provided with KPIs list in the Deliverable 1.6: Report on RINNO KPIs (v1), classified in the four main categories: technical/materials, social, economic, environmental KPIs.

Table 4-5. RINNO Key Requirements

Category	RINNO Key Requirements	Explanation	Guide for Relevant Phases in the Renovation Process
Technical aspects	Increased energy savings	All stakeholders in the renovation value chain have given high importance score for "energy savings" requirement according to stakeholder's key requirements & needs questionnaire results. Increased energy savings is considered one of main key RINNO requirements 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.	Planning and design phase and in the monitoring/operation phase
	Space saving (less invasive solutions)	Literature analysis confirmed that space saving is a important requirement/need for building owner and/or residents, tenant stakeholder. 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.	Planning and design stage
	Accuracy of the data gathering of the existing building	Literature review and questionnaire analysis show that designer stakeholder category has highlighted the crucial aspect as to how a building is operated closely relates to how the building allows its users to interact with it. As such, designers face the challenge not only to predict the building performance (internal temperatures, protection from the climate, etc.) but also to establish a degree of interaction between the occupant and the building. Such interaction is by its own dynamic nature hard to predict, and innovation in buildings (such as smart energy technologies, innovative materials as well as innovative design methods like BIM) makes this interaction potentially more complex. In here, the accuracy of the data gathering of the existing building and digital means and design methods appears crucial important in the renovation value chain.	Planning and design stage
	Effectiveness and replicability of the solutions and justification of the decision making process	An easy replication of the solutions within a building renovation process could support the decision making process thanks to the introduction of reference models or best practices along the renovation project.	Planning and design stage
Economical aspects	Life cycle cost savings/reduction	Questionnaire analysis results and literature review indicates that renovation costs (production, construction, use and end of life, maintenance costs) is the most important barrier to be addressed. All the stakeholders in the renovation value chain have indicated that the feasibility of an investment is a need for renovation value chain 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 will be important KPIs because they can increase the market uptake and acceptance rate of deep renovation solutions like the one introduced in RINNO.	Planning and design, construction/renovation and monitoring/operation renovation stages.
	Return on Investment		Planning and design phase
	Payback period		Planning and design phase

Category	RINNO Key Requirements	Explanation	Guide for Relevant Phases in the Renovation Process
	Installation time/costs/workforce saved (reduction of delivery, construction, design and installation time)	Reduction in installation time is been expressed as a crucial technical challenge to address with innovative renovation solutions by all stakeholders group. This is an important key requirement that is highlighted as 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. Besides, time savings during the design phase can be obtained due to innovative processes, e.g., use of cobots/robots, the amount of work conducted offsite, optimized logistics, etc	Construction/installation stage
Environmental aspects	Reduction of the greenhouse gases emissions and/or air pollutants-Environmental Life cycle GWP savings	Literature analysis and questionnaire analysis have highlighted that environmental life cycle GWP savings are an important key requirement to be measured in the renovation process. According to questionnaire analysis, CO_2 and other pollutant emissions reduction are highlighted with a high importance level mainly by public bodies and administration ad building Owner and/or resident stakeholders' groups. RINNO solutions directly contribute to the reduction of the energy demand of buildings, therefore to the decarbonization and the reduction of global warming potential in buildings.	Planning and design, construction/renovation and monitoring/operation renovation stages.
	Energy from renewable sources	Questionnaire analysis has indicated the importance of increasing the levels of energy efficiency and or decreasing energy consumption and/or by integrating cleaner energy sources, renewable energy production to build an environmentally friendly renovation process. 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 key requirement that will be expressed as a KPI.	Planning and design phase and monitoring/operation phase.
Materials	Use of bio-based materials Use of recyclable and recycled materials Reduce use of raw materials (Material use avoided) Waste Reduction	Literature analysis has indicated that one of the most important technical challenges for all renovation stakeholders is increasing the levels of the environmentally friendly renovation process. 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. Construction and demolition waste accounts for between 10% to 30% of total waste streams, of which 30-50% is attributed to renovation[49]. This requirement will be expressed as one KPI that 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.	Planning and design stage
Social aspects	Residents' comfort at the end of the renovation process:	Literature review and questionnaire responses indicate that acoustic improvement and protection against noise ate a need for building owner and &or resident stakeholder group. Besides these requirements are selected as key RINNO requirements due to some RINNO product innovations are	Planning and design and monitoring/operation renovation stages

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

Category	RINNO Key Requirements	Explanation	Guide for Relevant Phases in the Renovation Process
		aimed at address this requirement.	
	Acoustic insulation improvement Indoor Air quality improvement Thermal Comfort improvement	Across the EU, people spend approximately 90% of their time indoors. Conditions in these environments – temperature, lighting, humidity, draughts and noise, safety – play important roles in their physical and mental wellbeing. More efficient buildings improve thermal comfort for lower volumes of energy consumption, in turn reducing emissions and leading to better air quality both indoors and outdoors. The indoor air quality impacts human health and depends on some pollutant levels (e.g. dust, Volatile Organic Compounds (VOCs) etc.) and air conditions (e.g. CO2 and humidity). New and efficient ventilation systems and better insulation (avoiding increased humidity) have a positive impact on a better and healthy supply of air. These key requirements can be measured by defined KPIs that measures the proportion of the year when building occupiers are comfortable with the thermal conditions and air conditions inside a building and indirectly also measures the ability of a building to maintain pre-defined thermal comfort and air conditions, that will be improved with RINNO solutions.	Planning and design and monitoring/operation renovation stages Monitoring/Operation renovation stages.
	Residents' comfort during the renovation process: No need for the resident to leave the building during the works Time reduction on site (reduction of visits on site) Reduction of number of workers on site Integration of requests from residents Degree of discomfort of the occupants	Minimizing disturbance of tenants during renovation works is one of the key requirements that almost all stakeholders, mainly by building owner and/or resident stakeholder group, have highlighted high importance in the questionnaire. Prefabricated solutions developed in the project have a direct impact on the minimizing disturbance of tenants due to renovation works. The presence of a retrofitting manager can help to reduce the discomfort issues of the occupants during the renovation process.	Monitoring/Operation renovation stages.
	Site quality improvement: Reduction of accidents/ unforeseen event on site Easy collaboration with other stakeholders Easy collaboration with client/supplier Complaint management improvement Management of the material on site	Once renovation works start, the quality site and the quality control are important aspects of the process to take into account. The renovation works have to comply with quality requirements from a regulatory point of view, but also to align with the client's needs and expectations. Quality control is a continuous process that closely monitors construction daily, capturing potential quality control issues before they become expensive issues.	Monitoring/Operation phase.

5 RINNO Technologies/Solutions Catalogue and Preliminary Analysis for RINNO Technologies/Solutions Roadmap

Within chapter 5 of this document, an initial analysis of the technologies/solutions proposed by RINNO project partners have been carried out trying also to summirize the RINNO Technologies/Solutions Catalogue. The latter is aimed at populating, in a preliminary way, the RINNO Renovation Repository (RRR) taking into account the technology description, the innovation content and the market potential of each technology. Finally, the solutions identified within this activity have been analysed in order to develop a link between the RINNO requirement and the needs and the above-mentioned technologies.
The main outcomes of this section will be a fundamental starting point for the technology roadmap that will be finalized and presented at M24.

5.1 RINNO Technologies/Solutions Catalogue (Product Innovations)

The RINNO technologies/solutions proposed by the project partners have been collected with a catalogue aimed at summarizing the technology description, the innovative content, and the market potential complying with the disclosure partners requests. The catalogue presented in the next sections is part of the RINNO Renovation Repository (RRR).

5.1.1 Summary of RINNO Technologies & Solutions

In the following Table 5-1 a comparison of the previously described technologies has been developed, reporting the technology providers and the nature of energy performance improvement.
Considering the renovation approach promoted within the RINNO project, the different renovation technologies and solutions will be implemented in each demo-site during the first two years of the project, for this reason, the following description of the technologies and solutions could be adapted along with the project duration and they must be considered indicative at this stage of the project. The description of the technology packages is reported in the following sections.

Table 5-1. Summary of technologies and Solutions

Technology	Provider	Nature of energy performance improvement
MikroVent	EKOLAB	Constructive
Kompoment PV-Roof and Facade solutions	EKOLAB	Constructive
Isocell Cellulose Insulation	EKOLAB	Constructive
Bio-based double layer panels	K-FLEX	Constructive

Technology	Provider	Nature of energy performance improvement
Bio-based tubes and sheets	K-FLEX	Installation
K-box bio-based insulating system for the pipes of HVAC systems, PVs, Solar Panels	K-FLEX	Installation
Building Integrated Photovoltaic Glass	GREENSTRUCT	Renewable Energies
Thermochromic Glass	GREENSTRUCT	Constructive
De-centralized domestic hot water preparation	PINK	Installation

5.1.2 MicroVent – Sustainable Ventilation (In Ventilate – EKOLAB)

Table 5-2. MicroVent Technology/Solution Characterization

TECHNOLOGY DESCRIPTION	
TECHNOLOGY TITLE	**MICROVENT**
Leader Partner Name	EKOLAB
	
Technology Short description "MicroVent" is a facade integrated ventilation system with the lowest power consumption in the market and an 85-92% heat recovery. It is a patented intelligent control system, which enables units' collective response to ambient changes, reducing power consumption while optimizing user-comfort. The MicroVent-system consists of a minimum of two units working together; one unit removes air while the other supplies fresh air. They each have a regenerative heat exchanger that accumulates heat from the exhaust air and releases it when the air flow is reversed. The ventilation system is demand-controlled with variable air volume (VAV) based on CO_2, temperature and relative humidity.	
Innovation content The main Innovations to be conducted in the course of RINNO are: • Wireless communication and controlling. • New BUS-system replacing the existing Local Operating Network (LON). • Noise reduction using the newest ventilator-technology. • Possible exploitation of wind pressure to implement a unique compact solution for hybrid ventilation.	
MARKET POTENTIAL	
Sector(s) of application	Commercial, Residential
Result's Time to Market at the end of the project	MicroVent is currently developing a new system for improving sound levels and for measuring air pressure for a more intelligent control system. The advancements are expected to be ready for the demonstration on pilots.
Target Market	Residential, commercial
Market size and relevant trend:	The product is relevant for a large part of the building mass.
Potential customers	The product addresses customers in need for a simple ventilation solution.
Benefits to Building owner/residents/tenants/occupants or other stakeholder group in the renovation value chain	Building owners: a cost-effective solution to secure the buildings construction system from unwanted moisture, as well as an added value to the building due to an improved indoor climate in the building. Residents/Tenants/Occupants: Improved indoor climate, reduced heat consumption.

5.1.3 Kompromenent PV-Roof and Facade solutions (EKOLAB)

Table 5-3. Kompromenent PV-Roof and Facade Technology/Solution Characterization

TECHNOLOGY DESCRIPTION	
TECHNOLOGY TITLE	**KOMPROMENT PV-ROOF AND FACADE SOLUTIONS**
Leader Partner Name	EKOLAB
  	
Technology Short description Kompromenent PV roof and facade solution - Climate Cover is a universal envelope for both the roof and facades. It incorporates natural slate and solar cells. PV modules replaces ordinary roof materials, and this makes it more economic than add-on PV solutions. Some of the advantages of this technology are: • PV can be integrated with natural slate. • Energy production by the use of an integrated solar cell. • A hidden ventilation system. • A lightweight climate screen. • An easy and quick assembly/disassembly time.	
Innovation content The main Innovations to be conducted in the course of RINNO: • Reduction of costs in assembly systems. • Optimization of ventilation solution. • Localization of better price / performance on solar cells.	
MARKET POTENTIAL	
Sector(s) of application	Commercial, Residential
Result's Time to Market at the end of the project	Kompromenent is currently in the process of reducing costs and is in that context interested in the possibilities in combining products in a prefab solutions
Target Market	Residential, commercial
Market size and relevant trend:	The product is relevant for the most part of the building sector
Potential customers	The product addresses customers interested in cradle to cradle products and customers seeking aesthetically better integrated PV solutions to both the façade and roof area.
Benefits to Building owner/residents/tenants/occupants or other stakeholder group in the renovation value chain	Building owners: The solution can add value to the building due to a better aesthetical design compared to conventional PV façade systems. The cradle to cradle products may add signal value to the building. Residents/Tenants/Occupants: Aesthetical design

5.1.4 Isocell Cellulose Insulation (EKOLAB)

Table 5-4. Isocell Cellulose Insulation Technology/Solution Characterization

TECHNOLOGY DESCRIPTION	
TECHNOLOGY TITLE	**ISOCELL CELLULOSE INSULATION**
Leader Partner Name	EKOLAB
	ISOCELL CBIDanmark Cellulose Baseret Isolering 
Technology Short description Isocell Cellulose Insulation is a 90% bio-based material for insulating roofs, walls or ceilings, made of newspapers surplus upcycling. It consists of hollow cellulosic fibres, which have a fantastic insulating effect as opposed to massive fibres. The product has a high thermal insulation value and a high thermal capacity, combined with high airflow resistivity. Isocell also has a great resistance to setting.	
Innovation content The main Innovation to be conducted in the course of RINNO will be to find the best way to exploit this versatility in renovation projects, both on-site and with regards to prefabricated elements.	
MARKET POTENTIAL	
Sector(s) of application	Commercial, Residential
Result's Time to Market at the end of the project	CBI Isocell Cellulose Insulation is investigating how it can be integrated in hybrid prefab solutions.
Target Market	Residential, commercial
Market size and relevant trend:	The product is relevant for the most part of the building sector
Potential customers	The product addresses customers interested in a more environmentally friendly quality insulation product
Benefits to Building owner/residents/tenants/occupants or other stakeholder group in the renovation value chain	Building owners: The product insulates the building and improves heat loss performance Residents/Tenants/Occupants: Heat consumption reduced

5.1.5 Bio-based materials (K-FLEX POLSKA)

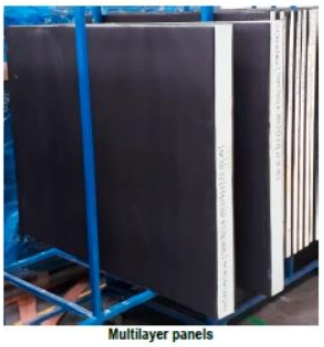
Table 5-5. Bio-based materials Technology/Solutions Characterization

TECHNOLOGY DESCRIPTION	
TECHNOLOGY TITLE	**BIO-BASED MATERIALS**
Leader Partner Name	K-FLEX

Ball valves with thermal insulation extension from DN 15 to DN 65

For STAD from DN 15 to DN 50

Biobased EPDM for insulation purpose



Multilayer panels

Technology Short description

In order to reduce heat losses, damp the sound transmission and reduce drastically the installation time, K-flex will contribute to RINNO project with three different products:

- Pipes and sheets based on Ethylene Propylene Diene Monomer (EPDM) with a high percentage of bio based content and increased fire resistance.
- Multi-layered panel with bio based polyurethane and compact rubber to realize insulating panel for refurbishing.
- K-box realized with the material mentioned in the first point.

The products are the following:

1. Bio-based double layer panels.
2. Multi-layered panel with bio-based (25-50%) polyurethane and compact rubber for insulating panels.
3. Bio-based pipes and sheets.
4. Pipes and sheets based on EPDM with a high percentage of bio-based content (45-60%) and increased fire resistance, which help reduce heat losses and dampen the sound transmission.
5. K-BOX bio-based insulating system for the pipes of HVAC systems, PVs and Solar Panels.

K-BOX is a preformed, removable, reusable insulation system, designed for components with complex shape and geometry. It consists of a Flexible Elastomeric Foam (FEF) insulation material mechanically preformed to fit exactly on multiple types of line components and is cladded by protection foil.

Some of the advantages that would be obtained by using this technology are:

- The material is easy to transport and mount owed to its easy bonding to different surfaces.
- Very short installation times, with reusability/adaptability on each case needs.
- It offers better insulation properties (~50%) compared to just wrapping the secondary equipment with standard material in sheets.
- Prevents completely condensation of air on the equipment.
- Reduces significantly (~30%) noise transmission.

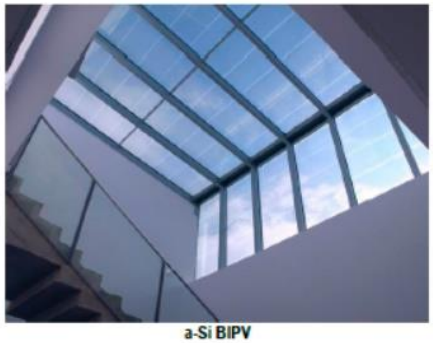
Innovation content

Main Innovations to be conducted in the course of RINNO:

• The new EPDM material realized with Biobased raw material and increased fire resistance properties, will be realized and demonstrated during the instalment of the various systems. • The new sandwich panel that will merge high thermal insulation properties with sound absorption and K-box is expected to achieve a reduction of installation time by roughly 95 percent.	
MARKET POTENTIAL	
Sector(s) of application	Not available at this stage of the project
Result's Time to Market at the end of the project	Not available at this stage of the project
Target Market	Not available at this stage of the project
Market size and relevant trend:	Not available at this stage of the project
Potential customers	Not available at this stage of the project
Benefits to Building owner/residents/tenants/occupants or other stakeholder group in the renovation value chain	Not available at this stage of the project

5.1.6 Building integrated Photovoltaic glass (GREENSTRUCT)

Table 5-6. Building integrated photovoltaic glass Technology/Solution Characterization

TECHNOLOGY DESCRIPTION	
TECHNOLOGY TITLE	**BUILDING INTEGRATED PHOTOVOLTAIC GLASS**
Leader Partner Name	GREENSTRUCT
 a-Si BIPV  c-Si BIPV	
Technology Short description Building Integrated Photovoltaic (BIPV) glass is an integrated structural-insulation-energy production element that can be used in different applications such as roofs, façades and canopies. BIPV glass is installed the same way as conventional glasses. Some of the advantages that would be obtained by using this technology are: - Significant savings in terms of renovation time (10 days less), space needed and costs (around 30%) in comparison with utilizing conventional insulation and PV modules. - Available in two types: a-Si PV glasses that come in a variety of colours and transparency and c-Si PV glasses that have higher yield resulting in high amounts of energy production. - Ease of installation. - Reduced maintenance needs.	
Innovation content The main innovation to be conducted in the course of RINNO will be the creation of a prefabricated aluminum module that will incorporate BIPV glass along with insulation panels on the back so that a ready to install panel with PV production capabilities can be made along with the most advanced insulating capabilities.	
MARKET POTENTIAL	
Sector(s) of application	Residential, Commercial
Result's Time to Market at the end of the project	Up until now the integrators used to place insulation in the building surface and then add the aluminium construction in order to support the bipv panels. Rinno project will introduce a prefabricated aluminium panel with bipv glass in front and insulation material on the back ready to be integrated to the building surface.
Target Market	Not available at this stage of the project
Market size and relevant trend:	Not available at this stage of the project
Potential customers	Not available at this stage of the project
Benefits to Building owner/residents/tenants/occupants or other stakeholder group in the renovation value chain	Not available at this stage of the project

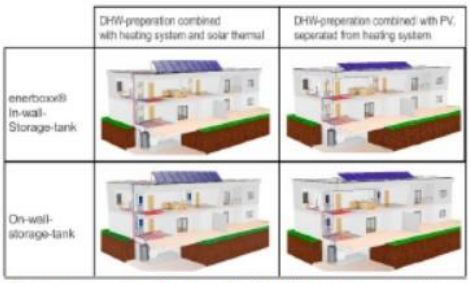
5.1.7 Thermochromic glass (GREENSTRUCT)

Table 5-7.Thermochromic Glass Technology/Solution Characterization

TECHNOLOGY DESCRIPTION	
TECHNOLOGY TITLE	**THERMOCHROMIC GLASS**
Leader Partner Name	GREENSTRUCT
 Thermochromic facade	 Thermochromic roof
Technology Short description Thermochromic glass is a newly developed technology that uses the sun heat to darken a glass pane in order to cut off all the harmful elements from entering a building. The core principle is that when the temperature on the surface of the glass rises, a thermochromic layer inside the triplex glass reacts and darkens resulting in a tinted glass while keeping the visibility at all times.	
Innovation content Up until now every glass surface in a building had a standard tint or no tint at all resulting in fixed technical properties such as G value, solar heat gain coefficient etc. This means that if we want to have a well insulated glass surface we must use a very dark tinted glass in order to block sun heat and all the damaging rays. But this tinted surface remains the same throughout the year resulting in minimized view as well as rejecting the desirable sun heat in winter times which is the most important. By using thermochromic glass we allow the sun heat to enter our building in winter and autumn and heat it up properly and rejecting the sun heat in summer creating that way a building that is self regulated in terms of energy allowance and rejection	
MARKET POTENTIAL	
Sector(s) of application	Residential, Commercial
Result's Time to Market at the end of the project	Up until now, thermochromic glass technology is being used in a very small scale mainly in large commercial projects. During Rinno project we will incorporate thermochromic glasses in prefabricated aluminium modules ready to be installed in the building as well as monitor all the internal space variables concerning energy conservation and comfort.
Target Market	Not available at this stage of the project
Market size and relevant trend:	Not available at this stage of the project
Potential customers	Not available at this stage of the project
Benefits to Building owner/residents/tenants/occupants or other stakeholder group in the renovation value chain	Not available at this stage of the project

5.1.8 De-centralized domestic hot water preparation (PINK)

Table 5-8. De-centralized domestic hot water preparation Technology/solution Characterization

TECHNOLOGY DESCRIPTION	
TECHNOLOGY TITLE	**DE-CENTRALIZED DOMESTIC HOT WATER PREPARATION**
Leader Partner Name	**PINK**
 **System approaches for de-centralized hot-water-preparation**	 **Different Storage tank types on dwelling level**
Technology Short description Hot water consumption can represent a large share of the total building energy use, depending on climate, occupancy type and building facilities. High temperatures are negatively influencing the overall efficiency of the installation in the means of heat losses and heat source efficiency. To counterbalance this effect, the proposed de-centralized DHW-solutions can be combined with the heating system and solar thermal, using a heat exchanger within the tank or separated from the heating system using a tank with a special electrical heating element, which can be integrated with PVs.	
Innovation content Some of the innovative elements this technology includes are: • Special heat exchanger design for low-temperature driving network. • BUS-connected controller. • Capacity indicator. • Connected metering systems. • Super-flat shape for low space consumption. • Pre-fabricated hydraulic modules. • New insulation materials for tanks. • Special materials and components of low maintenance needs. The advantages of this system in retrofit building projects, compared to standard ones, include: • Higher efficiency compared to a centralized system. • Low space consumption. • A short installation time. • A reduced maintenance cost (30%-50%). The main Innovation to be conducted in the course of RINNO is the inclusion of bio-based materials in collaboration with K-FLEX and ECOLAB.	
MARKET POTENTIAL	
Sector(s) of application	• Apartment buildings • Multi-storey residential buildings • Multifamily houses
Result's Time to Market at the end of the project	The product has already been installed and tested in real-life environments and meets its specifications (TRL7). During RINNO the inclusion of bio-based materials will be also examined in collaboration with K-FLEX and EKOLAB, prior to its possible demonstration, towards successful integration in

	real-life operational environment (TRL9).
Target Market	The main target market for the de-centralized storage tank is Austria und and partially Germany. During the RINNO project PINK will take advantage of the demonstration results for new opportunities for the products in at least 3 export markets. There is a technical and commercial cooperation in export nations planned to support the local customers.
Market size and relevant trend:	Due to the current state of development, only a few products have been installed so far. During the project period the number will amount to a few hundred, after the project one can assume a few thousand installations. Anyway, Pink plans a significantly grow in terms of turnover (increasing the export share from 10% to over 50%) and personnel due to export activities (expected increase of 20% in job openings).
Potential customers	• Engineering and Construction companies • Designer and Architects • Building owner and/or resident home owner • Housing associations
Benefits to Building owner/residents/tenants/occupants or other stakeholder group in the renovation value chain	• A highly efficient domestic hot water preparation • Option of low space consumption though the use of a wall-integrated version of the storage tank • Short installation time due to the prefabricated hydraulic modules • Reduced maintenance cost due the use of special materials and components

5.2 Preliminary analysis of RINNO technologies / Relevance matrix assessment (link between RINNO Key Requirements & Needs with RINNO Technologies/Solutions)

In the following paragraph, a preliminary assessment analysis of RINNO technologies/solutions (9 products) was performed aiming at te definition of the technological content of the products in order to be able to create a link among the key requirements, and needs and RINNO technologies/solutions. This activity has been carried out thanks to collaborative work between the technology providers partners of the RINNO project (EKOLAB, PINK, GREENSTRUCT and K-FLEX).

The RINNO key requirements, needs, barriers and challenges are selected thanks to results that comes from the questionnaire responses analysis, literature and synergy between task 1.4 of the RINNO project as described in Section 4.3 - RINNO Key Requirements.

As shown in Table 5-9, the relevance matrix assessment indicates the impact of the technologies/solutions that aim to address the key requirements defined within the previous activities of the RINNO Deliverable 1.1. Some of the requirements appear to be uncovered by the innovative solutions proposed, however, these requirements are mainly focused on the market, stakeholders' interaction, installation and operation procedures. Some of them will be taken into account during the next steps of the project with particular reference to demo cases and installation and use phase, while other aspects are expected to be evaluated in the long-term perspective.

Table 5-9. Relevance matrix -RINNO Technologies/solutions (Product Innovations) vs RINNO -Key Requirements & Needs

	MicroVent sustainable Ventilation system (EKOLAB)	Kompro ment PV-Roof and Facade solutions (EKOLAB)	Isocell Cellulose Insulation (EKOLAB)	Bio-based double layer panels(K-FLEX)	Bio-based tubes and sheets (K-FLEX)	K-BOX bio-based insulation system (K-FLEX)	Building Integrated Photovoltaic Glass (GREENSTRUCT)	Thermochromic Glass (GREENSTRUCT)	De-centralized domestic hot water preparation (PINK)
Energy savings	X		X	X	X	X		X	X
Life cycle cost savings/reduction	X	X	X	X	X	X	X	X	
Return on Investment			X						
Payback period									
Reduction of the greenhouse gases emissions and/or air pollutants- Environmental Life cycle GWP savings	X	X	X						
Use of bio-based materials				X	X	X		X	X
Use of recyclable and recycled materials	X	X	X	X	X	X	X	X	X
Reduction of Material use avoided	X			X	X	X			
Waste Reduction				X	X	X			
Energy from renewable sources		X					X		X

	MicroVent sustainable Ventilation system (EKOLAB)	Kompro ment PV-Roof and Facade solutions (EKOLAB)	Isocell Cellulose Insulation (EKOLAB)	Bio-based double layer panels(K-FLEX)	Bio-based tubes and sheets (K-FLEX)	K-BOX bio-based insulation system (K-FLEX)	Building Integrated Photovoltaic Glass (GREENSTRUCT)	Thermochromic Glass (GREENSTRUCT)	De-centralized domestic hot water preparation (PINK)
Installation time saved (reduction of delivery, construction, design and installation time)	X	X	X	X	X	X	X	X	X
Indoor Air quality improvement	X			X	X	X		X	
Thermal Comfort improvement (resident's comfort improvement)	X		X	X	X	X		X	X
Acoustic Improvement	X		X	X	X	X		X	
Space saving	X						X		X
No need for the resident to leave the building during the works	X	X	X						
Accuracy of the data gathering of the existing building									
Easy collaboration with other stakeholders									
Easy collaboration with client/supplier									
Integration of requests from residents									

	MicroVent sustainable Ventilation system (EKOLAB)	Kompro ment PV-Roof and Facade solutions (EKOLAB)	Isocell Cellulose Insulation (EKOLAB)	Bio-based double layer panels(K-FLEX)	Bio-based tubes and sheets (K-FLEX)	K-BOX bio-based insulation system (K-FLEX)	Building Integrated Photovoltaic Glass (GREENSTRUCT)	Thermochromic Glass (GREENSTRUCT)	De-centralized domestic hot water preparation (PINK)
Effectiveness and replicability of the solutions	X	X	X						
Complaint management Improvement									
Justification of the Decisions Making									
Time reduction on site (reduction of visits on site)	X	X	X						
Reduction of number of workers on site									
Reduction of accidents/ unforeseen event on site									
Support quality control (site quality improvement)									
Support to classification and organization of the material on site									
Establishment a degree of interaction between the occupant and the building									

5.3 Next steps - Roadmaps to TRL9

The final goal of this work is to define a technological roadmap for the RINNO innovative solutions identified within Section 5 of the present document, in order to draft pathways for technology development aiming to bring the RINNO technologies/solutions to their full commercialisation potential.

The roadmapping activities will be based on the characterization information collected and reported in the present document, that will be continuously updated during the course of the project in order to maintain them aligned with the actual status of development of the technologies as well as to include the main results of other activities and target applications for solutions' future marketability.

Starting from the technologies identified, with reference to the main requirements as well as the barriers and challenges identified, the main obstacles will be detected to address each of the innovative RINNO solutions from a technical, economic and environmental point of view.

In close collaboration with RINNO partners, which will provide and develop the technologies, mitigation and strategic actions as well as envisioned future steps of development will be identified, in order to provide a comprehensive view on the technical and commercial actions to be performed in the short and medium terms.
The overall roadmapping methodology is outlined in the following Figure 5.1.

Figure 5.1. Overall RINNO roadmapping methodology

Special attention will be reserved to technological aspects. A detailed assessment on the current status of technology development will be performed for each of the RINNO innovative solutions, in order to extract useful indications on further R&D activities needed at the end of the project for the solution to access the market. The technological roadmap of development will be based on the Technology Readiness level definition, reported in the Figure 5.2 below.

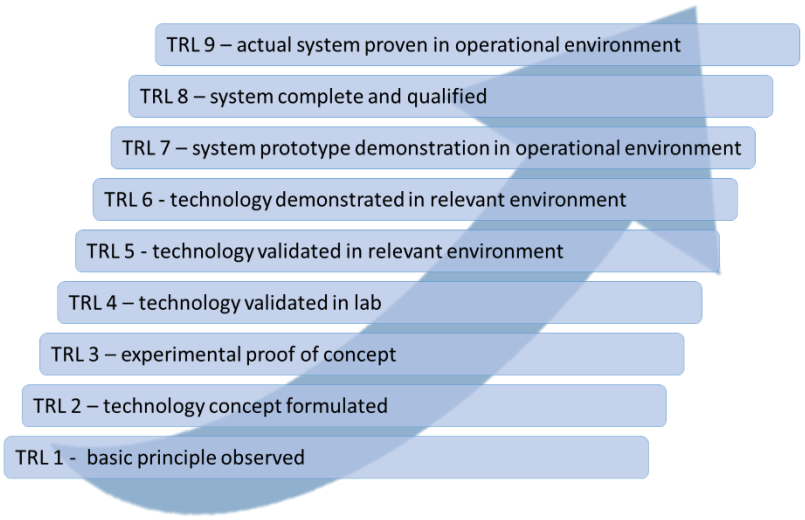


Figure 5.2. Technology Readiness Levels (TRL) definition[1]

In agreement with the project partners, the roadmapping activities will be developed in the following months and the main results will be included in the second version of the present document D1.2 *"RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (Final Version)"* due at M24 of the project.

6 Conclusions

The present report is a public deliverable (Deliverable D1.1 “RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (V1)”) of the RINNO H2020 funded European project, developed in the framework of the activities of Task 1.1 “Elicitation of Stakeholder Requirements & Market Needs”. The main scope of this report is to identify a set of key themes, including requirements, needs, barriers and challenges, from the point of view of different stakeholders involved in the renovation value chain.

The analysis has been based on a literature documentation review and questionnaire for data collection among stakeholders involved in the building renovation value chain. Starting from the main outcomes of the above-mentioned analysis, the RINNO key requirements have been defined and clusterised in the following categories: Technical aspects, Economical aspects, Environmental, Materials, Social aspects.

Final remarks, cosnidering the performed activities, can be summarized in the following points:

- ✓ **Technical aspects:** from the point of view of building energy consumption, the implementation of solutions that ensure energy savings represent a relevant point for all the stakeholder involved in the questionnaire filling. Accuracy of the data gathering of the existing building is a must-have requirement highlighted by the designers category, in one hand it is aimed at facilitating the data collection on the current building performance and in other hand it is aimed at predicting the performance of the building after the renovation process.
- ✓ **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 in use phase. The calculation costs phase must be taken into account with precise attention.
- ✓ **Environmental aspects:** the relevance of emission avoidance, including both GHG and other pollutants emission during the works as well as during building’s use phase is a common point of attention for interwiewed stakeholders. Also the possibility to integrate RES into the building, to reduce the impact of the building, through sustainable energy production is a relevant and valuable point to be condidered.
- ✓ **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.
- ✓ **Social aspects:** fundamental aspects to be carefully targeted and managed during the entire renovartion work are related to the engagement of owners and residents or occupants. Deep energy renovation needs a participative approach with early involvement of the users. In this sense, 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.

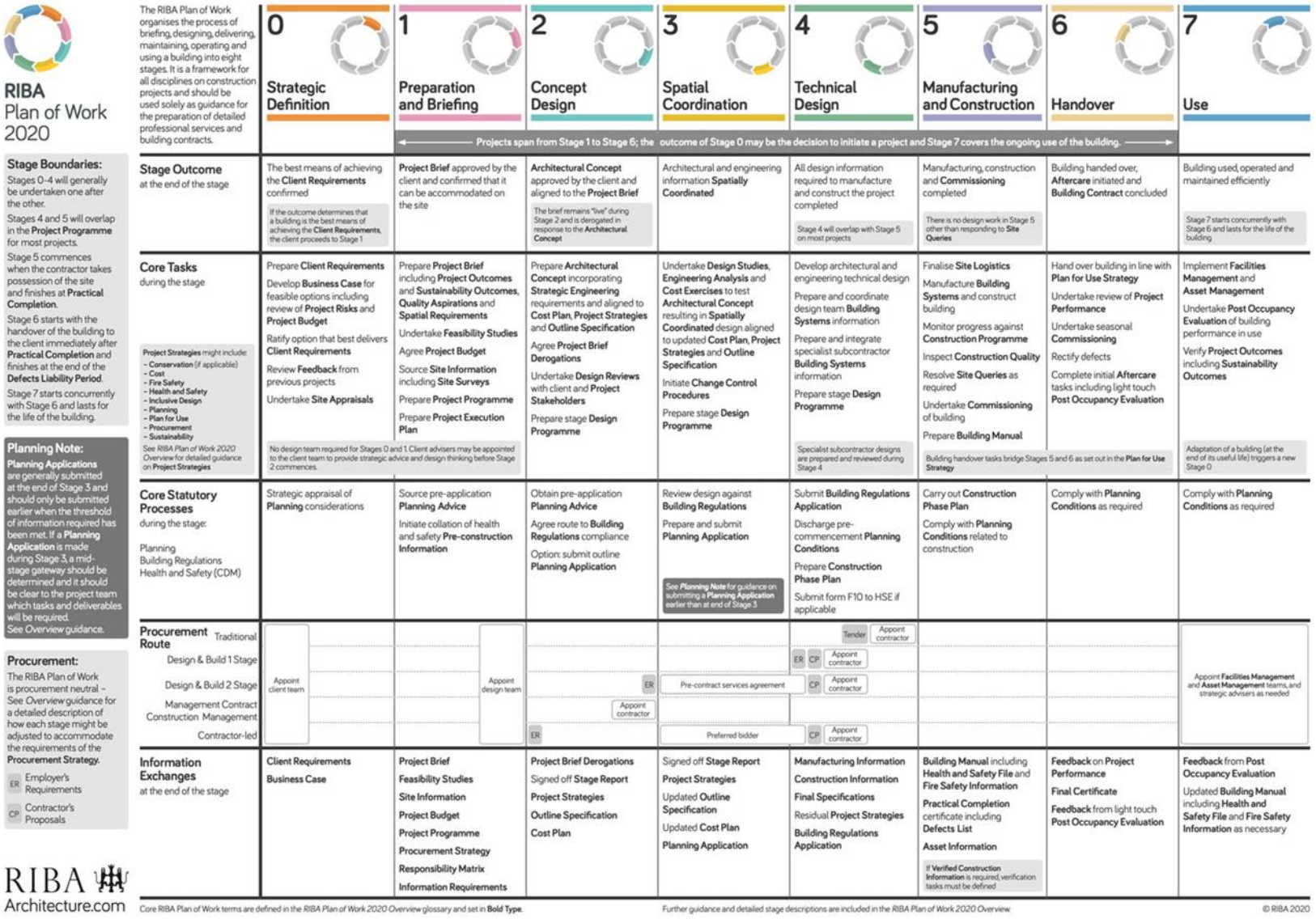
In parallel, technical and social barriers and challenges in renovation value chain have been identified. RINNO key requirements, barriers and challenges will allow the evaluation of RINNO technologies/solutions performance from a technical, economic, environmental and social perspective as a starting point of RINNO Technology Roadmap that will be finalised in M24.

The list of RINNO key requirements provided in this deliverable, will be revised and consolidated along the project and finalised and presented in the second release of this document (D1.2). The final version of this Deliverable (D1.2 “RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (final version)”) will contain an the finalised technology roadmap based on the expertise collected during use cases scenarios implementation in the framework of the WP6.

ANNEXES

ANNEX 1.
SELECTING THE STAGES IN THE BUILDING RENOVATION PROCESS

The scheme of stages according to the planning work set by RIBA Royal institute of British Architects is illustrated in the following picture.



RIBA Plan of Work 2020

The RIBA Plan of Work organises the process of briefing, designing, delivering, maintaining, operating and using a building into eight stages. It is a framework for all disciplines on construction projects and should be used solely as guidance for the preparation of detailed professional services and building contracts.

Stage Boundaries:
Stages 0–4 will generally be undertaken one after the other.
Stages 4 and 5 will overlap in the **Project Programme** for most projects.
Stage 5 commences when the contractor takes possession of the site and finishes at **Practical Completion**.
Stage 6 starts with the handover of the building to the client immediately after **Practical Completion** and finishes at the end of the **Defects Liability Period**.
Stage 7 starts concurrently with Stage 6 and lasts for the life of the building.

Planning Note:
Planning Applications are generally submitted at the end of Stage 3 and should only be submitted earlier when the threshold of information required has been met. If a **Planning Application** is made during Stage 3, a mid-stage gateway should be determined and it should be clear to the project team which tasks and deliverables will be required.
See *Overview* guidance.

Procurement:
The RIBA Plan of Work is procurement neutral – See *Overview* guidance for a detailed description of how each stage might be adjusted to accommodate the requirements of the **Procurement Strategy**.
ER Employer's Requirements
CP Contractor's Proposals

RIBA Architecture.com

	0 Strategic Definition	1 Preparation and Briefing	2 Concept Design	3 Spatial Coordination	4 Technical Design	5 Manufacturing and Construction	6 Handover	7 Use
	Projects span from Stage 1 to Stage 6; the outcome of Stage 0 may be the decision to initiate a project and Stage 7 covers the ongoing use of the building.							
Stage Outcome at the end of the stage	The best means of achieving the **Client Requirements** confirmed If the outcome determines that a building is the best means of achieving the **Client Requirements**, the client proceeds to Stage 1	**Project Brief** approved by the client and confirmed that it can be accommodated on the site	**Architectural Concept** approved by the client and aligned to the **Project Brief** The brief remains "live" during Stage 2 and is derogated in response to the **Architectural Concept**	Architectural and engineering information **Spatially Coordinated**	All design information required to manufacture and construct the project completed Stage 4 will overlap with Stage 5 on most projects	Manufacturing, construction and **Commissioning** completed There is no design work in Stage 5 other than responding to **Site Queries**	Building handed over, **Aftercare** initiated and **Building Contract** concluded	Building used, operated and maintained efficiently Stage 7 starts concurrently with Stage 6 and lasts for the life of the building
Core Tasks during the stage **Project Strategies** might include: – **Conservation** (if applicable) – **Cost** – **Fire Safety** – **Health and Safety** – **Inclusive Design** – **Planning** – **Plan for Use** – **Procurement** – **Sustainability** See *RIBA Plan of Work 2020 Overview* for detailed guidance on **Project Strategies**	Prepare **Client Requirements** Develop **Business Case** for feasible options including review of **Project Risks** and **Project Budget** Ratify option that best delivers **Client Requirements** Review **Feedback** from previous projects Undertake **Site Appraisals** No design team required for Stages 0 and 1. Client advisers may be appointed to the client team to provide strategic advice and design thinking before Stage 2 commences.	Prepare **Project Brief** including **Project Outcomes** and **Sustainability Outcomes**, **Quality Aspirations** and **Spatial Requirements** Undertake **Feasibility Studies** Agree **Project Budget** Source **Site Information** including **Site Surveys** Prepare **Project Programme** Prepare **Project Execution Plan**	Prepare **Architectural Concept** incorporating **Strategic Engineering** requirements and aligned to **Cost Plan**, **Project Strategies** and **Outline Specification** Agree **Project Brief Derogations** Undertake **Design Reviews** with client and **Project Stakeholders** Prepare stage **Design Programme**	Undertake **Design Studies**, **Engineering Analysis** and **Cost Exercises** to test **Architectural Concept** resulting in **Spatially Coordinated** design aligned to updated **Cost Plan**, **Project Strategies** and **Outline Specification** Initiate **Change Control Procedures** Prepare stage **Design Programme**	Develop architectural and engineering technical design Prepare and coordinate design team **Building Systems** information Prepare and integrate specialist subcontractor **Building Systems** information Prepare stage **Design Programme** Specialist subcontractor designs are prepared and reviewed during Stage 4	Finalise **Site Logistics** Manufacture **Building Systems** and construct building Monitor progress against **Construction Programme** Inspect **Construction Quality** Resolve **Site Queries** as required Undertake **Commissioning** of building Prepare **Building Manual** Building handover tasks bridge Stages 5 and 6 as set out in the **Plan for Use Strategy**	Hand over building in line with **Plan for Use Strategy** Undertake review of **Project Performance** Undertake seasonal **Commissioning** Rectify defects Complete initial **Aftercare** tasks including light touch **Post Occupancy Evaluation**	Implement **Facilities Management** and **Asset Management** Undertake **Post Occupancy Evaluation** of building performance in use Verify **Project Outcomes** including **Sustainability Outcomes** Adaptation of a building (at the end of its useful life) triggers a new Stage 0
Core Statutory Processes during the stage: Planning Building Regulations Health and Safety (CDM)	Strategic appraisal of **Planning** considerations	Source pre-application **Planning Advice** Initiate collation of health and safety **Pre-construction Information**	Obtain pre-application **Planning Advice** Agree route to **Building Regulations** compliance Option: submit outline **Planning Application**	Review design against **Building Regulations** Prepare and submit **Planning Application** See ***Planning Note*** for guidance on submitting a **Planning Application** earlier than at end of Stage 3	Submit **Building Regulations Application** Discharge pre-commencement **Planning Conditions** Prepare **Construction Phase Plan** Submit form F10 to HSE if applicable	Carry out **Construction Phase Plan** Comply with **Planning Conditions** related to construction	Comply with **Planning Conditions** as required	Comply with **Planning Conditions** as required
Procurement Route Traditional Design & Build 1 Stage Design & Build 2 Stage Management Contract Construction Management Contractor-led	Appoint client team	Appoint design team	ER Appoint contractor ER Pre-contract services agreement ER Preferred bidder	CP Appoint contractor	Tender Appoint contractor ER CP Appoint contractor CP Appoint contractor CP Appoint contractor			Appoint **Facilities Management** and **Asset Management** teams, and strategic advisers as needed
Information Exchanges at the end of the stage	**Client Requirements** **Business Case**	**Project Brief** **Feasibility Studies** **Site Information** **Project Budget** **Project Programme** **Procurement Strategy** **Responsibility Matrix** **Information Requirements**	**Project Brief Derogations** Signed off **Stage Report** **Project Strategies** **Outline Specification** **Cost Plan**	Signed off **Stage Report** **Project Strategies** Updated **Outline Specification** Updated **Cost Plan** **Planning Application**	**Manufacturing Information** **Construction Information** **Final Specifications** Residual **Project Strategies** **Building Regulations Application**	**Building Manual** including **Health and Safety File** and **Fire Safety Information** **Practical Completion** certificate including **Defects List** **Asset Information** If **Verified Construction Information** is required, verification tasks must be defined	**Feedback** on **Project Performance** **Final Certificate** **Feedback** from light touch **Post Occupancy Evaluation**	**Feedback** from **Post Occupancy Evaluation** Updated **Building Manual** including **Health and Safety File** and **Fire Safety Information** as necessary

Core RIBA Plan of Work terms are defined in the *RIBA Plan of Work 2020 Overview* glossary and set in **Bold Type**.

Further guidance and detailed stage descriptions are included in the *RIBA Plan of Work 2020 Overview*.

ANNEX 2:

QUESTIONNAIRE: ELICITATION OF STAKEHOLDER REQUIREMENTS & MARKET NEEDS, BARRIER AND CHALLENGES FOR BUILDINGS RENOVATION PROCESS

This questionnaire is proposed in the context of the project “RINNO: An augmented intelligence-enabled stimulating framework for deep energy renovation delivering occupant-centered innovations” funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 892071.

According to data from the EU building stock observatory, around 77% of the residential buildings have been constructed before 1990 and roughly 11% of Europe’s population still experiences energy poverty due to poor building quality, especially thermal efficiency. The EC 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 EU building stock. This calls for radically new approaches to deep energy renovation, along with novel technologies, processes and business models addressing the whole construction and renovation cycle.
This questionnaire aims at gathering information about the common practices and the main concerns of the stakeholders involved in the whole renovation value chain, the current barriers identified in the renovation processes and how which technology scenarios could help to overcome them. These subjects will be addressed through specific analyses by type of stakeholder and for each stage of the process in order to reach conclusions adjusted to the distinguishing needs and requirements.

RINNO aims at performing an analysis that engages all stakeholders across the value chain in order to define and evaluate key requirements for the whole value chain. In this sense, the RINNO consortium encompasses a broad construction stakeholders’ community, for liaison activities with construction-related entities that might be interested in the results and findings of the RINNO project.

As a member of the renovation value chain, we kindly ask you to provide your opinion on the different issues addressed on the renovation process.

We kindly ask you to review and answer the questions, in accordance to your own industrial or research expertise in the field of renovation.

Privacy Policy:

In May 2018 a new regulation on data protection entered into force: the General Data Protection Regulation (GDPR). More information can be found on the official website: www.eugdpr.org

Individuals benefit now from more rights to protect their personal data and we need your active consent to be able to send you the information requested.

After you subscribe for RINNO newsletter (https://rinno-h2020.eu/) you will receive an email to confirm your opt-in to our database. Please remember to click the link otherwise you won’t

be able to receive information from our side. Do not forget to check your spam or junk folder in case you do not receive said email!

PERSONAL INFORMATION

Please leave your contact information in order to be able to address any questions.

Your data will be processed in accordance with current legislation and will not be used for commercial purposes.

Contact Information:

Your data will be processed in accordance with current legislation and will not be used for commercial purposes. The register of the questionnaires will be treated with absolute confidentiality and their replies would be kept anonymous and added to the answers of the rest of the persons surveyed. Their contribution will help to compose the qualitative analysis and will only be used for the purposes of research in the study. You can contact us at the e-mail address listed below to request a change to your data or a copy of the data stored or for any technical problems in questionnaire.

Name and Surname:
Phone number:
E-mail:
Organization/institution
Country
Favourite Contact Method

Do you accept the conditions of treatment of my personal data according to art. 13 GDPR 679/16.

- Yes
- No

Are you a partner of RINNO project?

- Yes
- No

GENERAL INFORMATION ABOUT YOUR ORGANISATION

The objective of this section is to reach a wider general knowledge about your organisation and particularly about the renovation process in your organisation.

A1. What is the core business of your organisation?

- Architect/Designer
- Contractor
- Subcontractor
- Buildings ownership
- Software development or consultancy
- Supply
- Manufacturing
- External certificatory
- Regulator entity
- Financial entity
- Research & Development
- Services provider
- Professional association
- Others

A 1.1 Subcontractor
Please select your core business service(s)
(if the answer of A1 is Subcontractor answer this question)

- Site Preparation
- Data acquisition
- Foundations
- Structure
- Masonry
- Glass and Windows
- Electrical
- HVAC
- Plumbing
- Insulation
- Drywall
- Painting and Wall Covering
- Flooring
- Tile and Terrazzo
- Finish Carpentry
- Others

A 1.2 Buildings ownership
Please select your core business service(s)
(if the answer of A1 is Building Ownership answer this question)

- Building/home owners
- Buildings management
- Building administration
- Facility management/ Maintenance services

A2 Is your company/organization involved somehow in any stage of the renovation process?

- Yes
- No

A2.1 What is the most common building typology (according to use), you are involved with?
(if the answer of A2 is yes answer this question)

- Residential buildings
- Industrial buildings
- Commercial buildings
- Educational buildings
- Health buildings
- Offices

A2.2. Which typology of residential building, according to their size and ownership, do you most often renovate?
(if the answer of A2 is yes answer this question)

- Single family houses
- Terraced houses
- Apartment blocks/Tower buildings
- Groups of apartment blocks
- Other. Please specify:

A2.3 From the following phases of the renovation process, in which phase are you involved the most?
(if the answer of A2 is yes answer this question)

- Strategic Definition
- Information gathering and audit
- Renovation Conceptual Design
- Renovation Technical Project
- Construction
- Handover and close out
- In use

A2.4. Which typology of renovation works do you develop or promote the most?
(if the answer of A2 is yes answer this question)

- Inspection and maintenance works
- Internal refurbishment: (Painting, Floor / Wall tiling, Partition and internal space remodelling, Bathroom remodelling…)
- Interventions in the envelope (Framing and glazing replacement, Roof retrofitting…)
- Structural retrofitting (Column & Beams, Slabs, Load bearing Walls…)
- Service improvement (HVAC, RES, Electricity, Plumbing and Sewage, Fire security…)
- Accessibility improvement
- Overall renovation
- Other

A2.5 From your experience, in which phases of the renovation process most difficulties happen?
(if the answer of A2 is yes answer this question)

- Strategic Definition
- Information gathering and audit
- Renovation Conceptual Design
- Renovation Technical Project
- Construction
- Handover and close out
- In use

IDENTIFICATION OF THE REQUIREMENTS IN THE RENOVATION PROCESS

The objective of this section is to map different use cases in the renovation process with regard to phases of the process, stakeholders involved, typology of works etc. as well as the main requirements/expected benefits/barriers detected in the process, according to the role in the value chain of the respondent. Also, it is aimed at assessing the factors in a renovation process which have more relevance to the stakeholder according to the role in the value chain in a renovation process

B1 What is your main role in the construction/renovation process?

- Designer
- Contractor and subcontractor
- Building owner and/or resident
- Public administration as regulator entity
- Industrial (supplier, manufacturer, ESCOs, etc)
- Others (specify)

B1.A Designers

B1.A1 Designers / Please specify your specific role
(if the answer of B1 is Designer, answer this question)

- Project Manager
- Architect
- Structural Engineer
- Audit and data gathering
- Services Engineer
- Work controller
- Others (specify)

B1.A2 Designers / Following your role in the construction/renovation procesp please specify the importance for following requirements which could give value to your business, according to the impact on it.
(if the answer of B1 is Designer, answer this question)

1: Not Important 2: Slightly Important 3: Moderately Important 4: Important 5: Very Important

Key Requirements	1	2	3	4	5
Reduction of project development time					
Cost reduction					
Accuracy of the data gathering of the existing building					
Organisation of the documentation					
Improvement of the company's reputation					
Easy collaboration with the client					
Easy visualisation of the solution					
Integration of requests from residents					
Complaint management					
Justification of the Decisions Making Validation of the standards compliance in the project					
Reduction of the visits to site					
Create best practices					

Easy replication					
Prediction accuracy for the building performance (internal temperatures, protection from the climate, etc.)					
Establishment a degree of interaction between the occupant and the building					

B1.A3 Designers / Please specify if there is more key requirements/barriers/challenges in the construction/renovation process
(if the answer of B1 is Designer, answer this question)

B1.B Contractor and subcontractor
B1.B1 Contractor and subcontractor / Please specify your specific role
(if the answer of B1 is contractor and subcontractor, answer this question)

- Data gathering (scanner 3D, inspection, on-site measures, material tests..,)
- On site worker
- Cost controller
- Quality controller
- Installer
- Security manager
- Site manager
- Others

B1.B1 Contractor and subcontractor / Following your role in the construction/renovation process please specify the importance for following requirements which could give value to your business, according to the impact on it.
(if the answer of B1 is contractor and subcontractor, answer this question)

1: Not Important 2: Slightly Important 3: Moderately Important 4: Important 5: Very Important

Key Requirements	1	2	3	4	5
Reduction of execution works time					
Cost reduction					
Accuracy of the data gathering of the existing building					
Organisation of the documentation					
Improvement of the company's reputation					
Easy collaboration with the client					
Easy collaboration with suppliers					
Easy visualisation of the solution					
Integration of requests from residents					
Management of claims					
Justification of the Decisions Making					
Easy interaction with the designer					
Validation of the standards compliance on site					
Reduction of the visits to site					
Reduction of number of workers on site					
Reduction of accidents on site					
Reduction of unforeseen event on site					
Support to classification of the material on site					
Support to the control quality					
Easy replication					

Site quality Improvement (Water body preservation, Habitat preservation, Vegetation, Desertification, Rainwater runoff, heat island effect, Noise pollution, Light pollution, etc.)					

B1.B2 Contractor and subcontractor / Following your role in the construction/renovation process please specify the importance for following OPTIMIZED ECONOMICS requirements which could give value to your business, according to the impact on it.
(if the answer of B1 is contractor and subcontractor, answer this question)

1: Not Important 2: Slightly Important 3: Moderately Important 4: Important 5: Very Important

Key Requirements Optimized Economics	1	2	3	4	5
Technology R&D Cost					
Labor Cost					
Financing Cost					
Technology Application Cost					
Technology Designing Cost					
Technology Maintenance Cost					
Facility Management Cost					
Space & Infrastructure Costs					
People & Organization Costs					
Outdoors Costs					
Cleaning Costs					
Workplace Costs					
Primary activities specific Costs					
Logistics Costs					
Business support Costs					
Reduction of Energy Consumption					
Length of Payback Period					
Energy-Saving Consciousness of Occupants					
Level of Marketization of Technology and Product-Marketability					
Level of Massive Development of Technology and Product					
Longer building lifetime					
Increase in the building value					

B1.B3 Contractor and subcontractor / Please specify if there is more key requirements/barriers/challenges in the construction/renovation process
(if the answer of B1 is contractor and subcontractor, answer this question)

B1.C Building owner and/or resident

B1.C1 Building owner and/or resident / Please specify your specific role
(if the answer of B1 is building owner rand/or resident, answer this question)

- Home owner
- Housing associations (as an owner)
- Resident/Occupants/tenants
- Property owners (social housing association)
- Buildings manager
- Building administrator
- Facility manager/ Maintenance

- Others

B1.C2 Building owner and/or resident / Following your role in the construction/renovation process please specify the importance for following ENVIRONMENTAL requirements which could give value to your business, according to the impact on it.
(if the answer of B1 is building owner rand/or resident, answer this question)

1: Not Important 2: Slightly Important 3: Moderately Important 4: Important 5: Very Important

Key Requirements Environmental	1	2	3	4	5
Energy Consumption					
Energy delivery performance					
Energy uses disaggregation in conditioned space					
Energy uses disaggregation in not conditioned space					
Total CO2 emission /reduction					
Other pollutant emissions reduction (NOx, SOx & particulate matter emissions)					
Share of energy sources (Solid energy fuels, LNG, fuel, renewable energy source)					
Eco labelling (LEED, BREEAM, CASBEE...) of the building after renovation					

B1.C3 Building owner and/or resident / Following your role in the construction/renovation process please specify the importance for following OPTIMIZED ECONOMICS requirements which could give value to your business, according to the impact on it.
(if the answer of B1 is building owner rand/or resident, answer this question)

1: Not Important 2: Slightly Important 3: Moderately Important 4: Important 5: Very Important

Key Requirements Optimized Economics	1	2	3	4	5
Technology R&D Cost					
Labor Cost					
Financing Cost					
Technology Application Cost					
Technology Designing Cost					
Technology Maintenance Cost					
Facility Management Cost					
Space & Infrastructure Costs					
People & Organization Costs					
Outdoors Costs					
Cleaning Costs					
Workplace Costs					
Primary activities specific Costs					
Logistics Costs					
Business support Costs					
Reduction of Energy Consumption					
Length of Payback Period					
Energy-Saving Consciousness of Occupants					
Level of Marketization of Technology and Product-					

Marketability					
Level of Massive Development of Technology and Product					
Longer building lifetime					
Increase in the building value					

B1.C4 Building owner and/or resident / Following your role in the construction/renovation process please specify the importance for following HEALTH, COMFORT&SAFETY requirements which could give value to your business, according to the impact on it.
(if the answer of B1 is building owner rand/or resident, answer this question)

1: Not Important 2: Slightly Important 3: Moderately Important 4: Important 5: Very Important

Key Requirements HEALTH AND COMFORT	1	2	3	4	5
Aesthetics (Building Aesthetics, Landscape Aesthetics, Aesthetical environment)					
Air infiltration rate (Building Air tightness, Systems and HVAC airtightness)					
Indoor Air quality improvement (Mechanical ventilation, Low-emitting materials, Indoor chemical & pollutant source control, Thermal Comfort improvement, Under cooled periods, Over heated periods, Operative Temperature, Humidity, Adaptive comfort approach, Moisture Comfort improvement)					
Thermal Comfort improvement (Under cooled periods, Over heated periods, Operative Temperature, Humidity, Adaptive comfort approach, Moisture Comfort improvement)					
Acoustic performance improvement (Acoustic quality)					
Daylight and views improvement (Illumination levels, % of space with natural light and views, Glare control)					
Ergonomic Workplace improvement					
No need for the resident to leave the building during the works					
Adaptation to changes in comfort expectations and in occupancy trends (such as teleworking, co-working, and home-sharing)					
Building Safety (Earthquake resistance, Tornado resistance, Flood resistance, Fire safety, hazardous material elimination, Electrical safety, Slip and trip protection)					

B1.C5 Building owner and/or resident / Please specify if there is more key requirements/barriers/challenges in the construction/renovation process

B1.D Public administration as regulator entity:

B1.D1 Public administration as regulator entity / Please specify your specific role
(if the answer of B1 is public administration as regulator entity, answer this question)

- Council/local authority (as an owner)
- Security authority
- Waste manager
- Industrial Department
- Others (please specify)

B1.D2. Public administration as regulator entity / Following your role in the construction/renovation process please specify the importance for following requirements which could give value to your business, according to the impact on it.
(if the answer of B1 is public administration as regulator entity, answer this question)

1: Not Important 2: Slightly Important 3: Moderately Important 4: Important 5: Very Important

Key Requirements	1	2	3	4	5
Energy savings					
Cost reduction					
Access to financial subsidies					
Maintenance cost reduction					
Resident's comfort improvement					
CO2 and other pollutant emissions reduction					
Support to the control quality					
Longer building lifetime					
Aesthetic improvement of the building					
No need for the resident to leave the building during the works					
Accuracy of the data gathering of the existing building					
Organisation of the documentation					
Improvement of the company's reputation					
Easy collaboration with other stakeholders					
Easy visualisation of the solution					
Integration of requests from residents					
Complaint management					
Justification of the Decision Making					
Reduction of accidents on site					
Reduction of unforeseen events on site					
Reduction of delivery time					

B1.D3. Public administration as regulator entity / Please specify if there is more key requirements/barriers/challenges in the construction/renovation process
(if the answer of B1 is public administration as regulator entity, answer this question)

B1.E Industrial

B1.E1 Industrial / Please specify your specific role
(if the answer of B1 is industrial, answer this question)

- Supplier
- Manufacturer
- ESCOs
- Others

B1.E2 Industrial / Following your role in the construction/renovation process please specify the importance for following requirements which could give value to your business, according to the impact on it.
(if the answer of B1 is industrial, answer this question)

1: Not Important 2: Slightly Important 3: Moderately Important 4: Important 5: Very Important

Key Requirements	1	2	3	4	5
Reduction of delivery time					
Reduction of construction time					

Cost reduction					
Organisation of the material onsite					
Accuracy of the data gathering of the existing building					
Organisation of the documentation					
Improvement of the company's reputation					
Easy visualisation of the solution					
Integration of requests from residents					
Complaint management					
Easy interaction with the contractor					
Easy interaction with the designer					
Validation of the standards compliance					

B1.E3 Industrial / Please specify if there is more key requirements/barriers/challenges in the construction/renovation process
(if the answer of B1 is industrial, answer this question)

B1.F Others

B1.F1 Others / Please specify your specific role
(if the answer of B1 is others, answer this question)

- Software developer or consultant
- External certificatory
- Funders
- Education and training on renovation value chain
- Others

B1.F2 Others / Following your role in the construction/renovation process please specify the importance for following requirements which could give value to your business, according to the impact on it.
(if the answer of B1 is others, answer this question)

1: Not Important 2: Slightly Important 3: Moderately Important 4: Important 5: Very Important

Key Requirements	1	2	3	4	5
Energy savings					
Cost reduction					
Access to financial subsidies					
Maintenance cost reduction					
CO2 and other pollutant emissions reduction					
Support to the control quality					
Longer building lifetime					
Aesthetic improvement of the building					
No need for the resident to leave the building during the works					
Eco labelling (LEED, BREEAM, CASBEE...) of the building after renovation					
Increase in the building value					
Accuracy of the data gathering of the existing building					
Organisation of the documentation					
Improvement of the company's reputation					
Easy collaboration with other stakeholders					
Easy visualisation of the solution					
Integration of requests from residents					

Complaint management					
Justification of the Decision Making					
Validation of the standards compliance					
Reduction of accidents on site					
Reduction of unforeseen events					
Reduction of delivery time					

POTENTIAL TO OVERCOME THE BARRIERS & CHALLENGES IN RENOVATION PROCESS THROUGH "TECHNOLOGY"

The objective of this chapter is to identify how TECHNOLOGIES can help to overcome the barriers and challenges in renovation processes and to define the requirements that technology must have to meet the demands of the respondent as a part of the renovation process.

The project will offer a portfolio of innovative technologies and processes in order to address the various barriers and challenges faced by the building renovation market, aiming at delivering a reliable and cost-effective renovation process that is attractive to stakeholders, environmentally friendly, and causes less disruption to the residents than the conventional renovation practices.

The deep Renovation value chain has tackled the main barriers of deep-renovation through the search for innovative technological solutions to overcome the obstacles present in the market of energy requalification

- Technical barriers;
- Social barriers

The technical feasibility of deep renovation measures is of great importance for the achievement of proven-quality results. The main challenges in the deep renovation processes will be evaluated as the following macro-groups.

- Technical Challenges
- Social Challenges

Following your role in the construction/renovation process please specify the importance for following TECHNICAL and SOCAL barriers & challenges which could give value to your business, according to the impact on it.

1: Not Important
2: Slightly Important
3: Moderately Important
4: Important
5: Very Important

C1.1 Technical Barriers

Key Technical Barriers	1	2	3	4	5
A lack of consistent and standardized solutions or integrated solutions to comply with new and different building standards requirements on energy saving;					
Lack of skilled and experienced resources (workers) to carry out the work					

Shortcomings in technical solutions, and long processes discouraging owners					
Safety/seismic risk connected with the deep renovation processes (damages can be done to the homes while retrofitting or unsure perception of the current safety of the existing buildings					
End users' and owners' lack of technical expertise and trust in effective energy renovation savings					

C1.2 Social Barriers

Key Social Barriers	1	2	3	4	5
Decision-making processes that are long and complex, especially in cases of multi-owner houses (condominiums)					
The lack of consensus, understanding, and support from the inhabitants that often hinder the effective approval of the interventions					
The problem of disturbance during site works and/or relocation (in case owners/users need to leave their homes during the process)					
Low awareness about energy efficiency and non-energy benefits of renovation					
Lack of dialogue between the different stakeholders					

C1.3 Please specify if there is more technical or social barriers in the construction/renovation process

C1.4 Technical Challenges

Key Technical Challenges	1	2	3	4	5
Integrated technical solution packages with aiming improving performance					
Reducing time and complexity of the interventions					
Delivering a reliable and cost-effective renovation process					
Environmentally friendly renovation process					
Less disruption to the residents than the conventional renovation practices					
Easy to install (plug-n-play) technologies					
Increasing the levels of energy efficiency and renewable energy production					
Standardized solutions that can be easily applied to achieve compliance to different building standards					

C1.5 Social Challenges

Key Social Challenges	1	2	3	4	5
Education and confidence in construction professionals					
Consumer acceptance of new technologies and innovative renovation solutions					
Knowledge of available solutions and customizability					

Reducing Disruption factor (refers to all the troubles linked to refurbishment work for the occupant)					
Decision-making in condominiums					

C1.6 Please specify if there is more technical or social challenges in the construction/renovation process

Thank you for participating!!!

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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7 REFERENCES

1. https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf
2. BUILDHEAT project website: http://www.buildheat.eu/
3. BUILDHEAT "*D5.2 - Managing Human Factors in Retrofit Projects":* http://www.buildheat.eu/wp-content/uploads/2020/05/D5.2-Managing-the-human-factors-in-retrofit-process.pdf
4. BUILDHEAT "*D6.4 – Financing models for deep retrofit actions*": http://www.buildheat.eu/wp-content/uploads/2020/05/WP6-D6.4-Financing-models-for-deep-retrofit-solutions.pdf
5. NEED4B project website: http://need4b.eu/
6. NEED4B "*D2.8: Final version of the methodology after the design, construction and monitoring program*": http://need4b.eu/wp-content/uploads/2018/02/NEED4B_D2.8_Final-version-of-the-methodology-after-the-design-construction-and-monitoring-program.pdf
7. NEED4B *"D2.5 LCA and LCC during the design, construction and operation phases"* http://need4b.eu/wp-content/uploads/2018/02/NEED4B_D2.5_LCA-and-LCC-during-the-design.pdf
8. OptEEmal project website: https://www.opteemal-project.eu/
9. OptEEmal "*D6.3 Report on stakeholders and IPD implementation to demonstrate the OptEEmAL platform*": https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c1fd1fc8&appId=PPGMS
10. ENERGY IN TIME project website: https://www.energyintime.eu/
11. Gómez-Romero, J.; Molina-Solana, M.; Ros, M.; Ruiz, M.D.; Martin-Bautista, M.J. Comfort as a Service: A New Paradigm for Residential Environmental Quality Control. Sustainability 2018, 10, 3053. https://doi.org/10.3390/su10093053
12. STUNNING project website: https://stunning-project.eu/
13. STUNNING "*D4.1 – Energy Efficiency renovation market mechanisms, trends and barriers":* https://renovation-hub.eu/wp-content/uploads/2019/09/D4.1_FINAL-15.pdf
14. BIM4Ren project website https://bim4ren.eu/
15. BIM4Ren *"D1.1 Stakeholders requirements and constraints, Building Information Modelling based tools & technologies for fast and efficient RENovation of residential buildings":* https://bim4ren.eu/download/d1-1-stakeholders-requirements-and-constrains/
16. POCITYF project website https://pocityf.eu/
17. POCITYF "*D1.1: End-User and Stakeholders Requirements Definitions":* https://pocityf.eu/wp-content/uploads/2020/09/POCITYF-864400_D1.1_End-User-and-Stakeholders-Requirements-Definition-1.pdf
18. EuroPHit project website: https://europhit.eu/
19. EuroPHit - Handbook for step-by-step retrofits with Passive House Components https://europhit.eu/sites/europhit.eu/files/EuroPHit_Handbook_final_Optimized.pdf
20. Renovation wave, 2020, available at: https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en
21. Global Buildings Performance Network - What Is A Deep Renovation Definition? – Technical Report – 2013 https://www.gbpn.org/sites/default/files/08.DR_TechRep.low_.pdf
22. Energy Efficient Directive, available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:en:PDF
23. The Royal Institute of British Architects is a global professional membership body in

architecture.
24. RIBA Plan of Work 2020 Edition - https://www.architecture.com/-/media/GatherContent/Test-resources-page/Additional-Documents/2020RIBAPlanofWorktemplatepdf.pdf
25. Aapaoja A., Haapasalo H., 2014., A Framework for Stakeholder Identification and Classification in Construction Projects. Open Journal of Business and Management, 2014, 2, 43-55.
26. Aapaoja A., Haapasalo H., 2014., A Framework for Stakeholder Identification and Classification in Construction Projects. Open Journal of Business and Management, 2014, 2, 43-55.
27. Brown, P., Swan, W. and Chahal, S., 2014. Retrofitting social housing: reflections by tenants on adopting and living with retrofit technology. Energy Efficiency, 7(4), pp.641-653.
28. Seligman, C., Darley, J.M. and Becker, L.J., 1978. Behavioral approaches to residential energy conservation. Energy and buildings, 1(3), pp.325-337.
29. International Energy Agency, 2018, *"Occupant behaviour-centric building design and operation EBC Annex 79",* available at: https://annex79.iea-ebc.org/
30. Swan, W., 2013. Retrofit innovation in the UK social housing sector: a socio-technical perspective. Retrofitting the Built Environment, pp.36-52.
31. Tweed, C., 2013. Socio-technical issues in dwelling retrofit. Building Research & Information, 41(5), pp.551-562.
32. Fink, H.S., 2011. Promoting behavioral change towards lower energy consumption in the building sector. Innovation: The European Journal of Social Science Research, 24(1-2), pp.7-26.
33. Sherriff, G.A. and Swan, W., 2016. Greater Manchester green deal communities programme scheme exit paper.
34. Haines, V. and Mitchell, V., 2014. A persona-based approach to domestic energy retrofit. Building Research & Information, 42(4), pp.462-476.
35. Howden-Chapman, P., Crane, J., Matheson, A., Viggers, H., Cunningham, M., Blakely, T., O'Dea, D., Cunningham, C., Woodward, A., Saville-Smith, K. and Baker, M., 2005. Retrofitting houses with insulation to reduce health inequalities: aims and methods of a clustered, randomised community based trial. Social science & medicine, 61(12), pp.2600-2610.
36. European Environment Agancy, 2020, "Air quality in Europe", available at: www.eea.europa.eu/publications/air-quality-in-europe-2020-report
37. United Nations , 2018, "Political declaration of the third high-level meeting of the General Assembly on the prevention and control of non-communicable diseases", available at: www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/73/2
38. Hens, H., 2010. Energy efficient retrofit of an end of the row house: confronting predictions with long-term measurements. Energy and buildings, 42(10), pp.1939-1947.
39. BPIE (2019), "Building 4 People: Valorising the Benefits of Energy Renovation Investments in Schools, Offices and Hospitals", available at: http://bpie.eu/publication/building-4-people-valorising-the-benefits-of-energy-renovationinvestments-in-schools-offices-and-hospitals/
40. Arup Group, 2020, Future of offices: in a post-pandemic world, available at: https://www.arup.com/-/media/arup/files/publications/f/future-of-offices-in-a-post-pandemic-world.pdf
41. BIM4EEB, D2.2 List of Designers' Needs and Requirements for BIM-Based Renovation Processes, available at: https://www.bim4eeb-project.eu/media/doc/D2.2.pdf
42. BUILDUP "Building operation: the elusive alignment of research, design and occupants", available at: https://www.buildup.eu/en/node/57424
43. Frödell, M. (2011), "Criteria for achieving efficient contractor-supplier relations", Engineering, Construction and Architectural Management, Vol. 18 No. 4, pp. 381-393, available at: https://doi.org/10.1108/09699981111145826
44. European Union and the Committee of the Regions, Renovation wave and local and

regional authorities: policy and tools to build capacity and finance projects, 2020, available at: https://cor.europa.eu/en/engage/studies/Documents/Renovation%20wave%20and%20local%20and%20regional%20authorities%20-policy%20and%20tools%20to%20build%20capacity%20and%20finance%20projects/Renovation%20Wave_Study.pdf
45. AIP Conference Proceedings 2020, 020049 (2018); https://doi.org/10.1063/1.5062675 Published Online: 05 October 2018
46. https://www.iea.org/reports/energy-service-companies-escos-2/esco-contracts
47. A2PBEER (GA n.60960), ABRACADABRA (GA n.696126), ADAPTIWALL (GA n.608808), BERTIM (GA n.636984), BRESAER (GA n.637186), BuildHEAT (GA n.680658), CETIEB (GA n.285623), E2VENT (GA n.637261), EASEE (GA n.285540), EENSULATE (GA n.723868), HERB (GA n.314283), IMPRESS (GA n.636717), INSITER (GA n.636063), iNSPiRe (GA n.691440), MeeFS (GA n.285411), MORE-CONNECT (GA n.633477), NewTREND (GA n.680474), OptEEmal (GA n.680676), P2Endure (GA n.732391), REFURB (GA n.649865), REnnovates (GA n.680603), RetroKit (GA n.314229), RE4 (GA n.723583), VEEP (GA n.723582), TransitionZero (GA n.696186), 4RinEU (GA n.723829), IEE ZEBRA 2020, IEE NeZeR, smarTES (ERA-Net WoodWisdom-Net 2004-2008)
48. D'Oca S., Ferrante A., Ferrer C., Pernetti R., Gralka A., Sebastian R. and Veld P., 2018., Technical, Financial, and Social Barriers and Challenges in Deep Building Renovation: Integration of Lessons Learned from the H2020 Cluster Projects. Buildings
49. Balaras C.A., Droutsa K., Dascalaki E., Hansen K. and Petersen E.H., Environmental Impact Assessment of Residential Buildings, INVESTIMMO Project, FP5-Growth