RINNO

RINNO PROJECT

Report

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

Deliverable 1.2: RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (Final version)

Work Package 1: RINNO Augmented Intelligence Renovation Framework

RINA-C

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Executive Summary

This report presents second and final version of the deliverable "*RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9*" based on the analysis and definition of stakeholders' expectations from improved renovation processes and innovative technology solutions. This version starts from the information gathered in the first phase of the project and that are present in the first version, making a final review of the key requirements and needs of stakeholders in the building renovation process and the social, technical and financial barriers and challenges faced.

In order to develop this final version, the following main activities were conducted to date:

- A review of the key requirements and needs of stakeholders in the building renovation process;
- A review of all the technical, financial, and social barriers and challenges that can be faced during this process;
- Association of the KPIs to the Key Requirements for deep renovation process, based on what emerged from T 1.4 "*Building Renovation Assessment KPIs*" and reported in D 1.7 "*Report on RINNO KPIs (Final Version)";*
- Analysis of the objectives considered, by the occupants of the demo buildings, as most important, based on what emerged from T 1.3 "*Pilot Sites Surveys & Definition of Use Case Renovation Scenarios*" and reported in D 1.4 "*RINNO Pilot Analysis and Deployment Plan (V1)";*
- Matching the RINNO technology solutions with the selected key requirements and indicating the expected impacts of these solutions;
- The final Roadmap to TRL9 methodology that will be adopted within the RINNO project.

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BIM	Building Information Modeling Bottom of Form
BIPV	Building Integrated Photovoltaic
BM	Business Model
BRP	Building Renovation Passports
DHW	Domestic Hot Water
EC	European Commission
EE	Energy Efficiency
EPC	Energy Performance Contracting
EPBD	Energy Performance of Buildings Directive
EPDM	Ethylene Propylene Diene Monomer
ESCO	Energy Service Company
GHG	Greenhouse Gases
GWP	Global Warming Potential
HVAC	Heating, Ventilation, and Air Conditioning
KPI	Key Performance Indicator
NZEB	Nearly Zero Energy Building
PEB	Positive Energy Building
PUR	Polyurethane
PV	Photovoltaic
R&D	Research and Development
RES	Renewable Energy Sources
SBR	Styrene-Butadiene Rubber
TRL	Technology Readiness Level
VOC	Volatile Organic Compounds
WP	Work Package

1 Introduction

The present report is a public deliverable (Deliverable D1.2 "RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9_Final Version") of the RINNO H2020 funded European project, developed in the framework of the activities of Task 1.1 "Elicitation of Stakeholder Requirements & Market Needs".

1.1 RINNO Project

According to the European Commission (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.

Please refer to D1.1 for a more detailed description of the project.

1.2 Scope and Objectives of Deliverable 1.2

This deliverable represents the final version of "*RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9*" and the main scope is to update the preliminary list of key requirements from the perspectives of different stakeholders in the building renovation value chain, identified during the previous activities and reported in D1.1, and to perform a TRL assessment in order to define a TRL 9 roadmap for each exploitable result.

The first part (chapter 2) of the document is dedicated to the RINNO requirements and barriers in the building renovation process. To complete the key requirements description, we reported the list of building renovation KPIs, based on the D1.7 "Report on RINNO KPIs". These KPIs will be taken into consideration for the RINNO evaluation and impact assessment in technical, economic, environmental, and social terms.

This section contains also an insight of lessons learnt directly from demo cases, analysed during the Task 1.3 "Pilot Sites Surveys & Definition of Use Case Renovation Scenarios" and included in the deliverable D1.4 "RINNO Pilot Analysis and Deployment Plan".

The second part (chapter 3) of the deliverable is focused on the exploitable results, their characterization and TRL 9 roadmaps. Thanks to the partners' contribution, we reported a more detailed characterization table that include specific information such as:

- A detailed description of the innovative content of the developed technology;
- Information about the market maturity (*Not yet existing, Emerging or Mature*);
- Potential end users (if different from customers);
- Potential main competitors;
- Unique value proposition (against competitor's solutions).

The TRL 9 roadmap was build based on a specific questionnaire through which a variety of information was collected, including:

- R&D activities performed so far within the project to reach the actual TRL;
- Necessary expected R&D activities to reach the TRL intended to be reached at the end of the project and also to reach TRL 9 (if not reached within the project);
- Main foreseen barriers to obtain what is intended to be achieved;
- High-level indication on expected costs and years of R&D needed to TRL 9.

The conclusions are reported in chapter 4.

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 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 have been identified to quantify the identified stakeholders' needs and requirements. These requirements are expressed by the group of KPIs selected in the Deliverable 1.7 and reported in this report.

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 have been the baseline for the RINNO improvements evaluation. Figure shows the interactions among the different tasks in WP1.

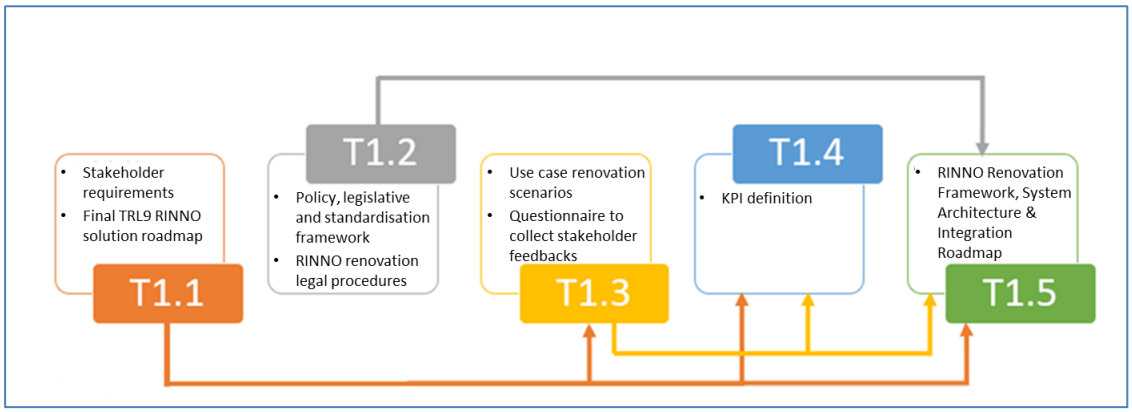


Figure 1-1. RINNO WP1 interaction.

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

RINNO KPIs (T1.4) have been 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 Identification of Stakeholders' requirements

2.1 Literature review for requirements identification

In order to collect the key requirements and the needs along the entire building renovation value chain, the first version of this deliverable (D1.1) reported a desk search analysis performed taking into account 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 and administration", "Contractors and subcontractor", "Industrials"* and *"Others"*. 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.

In this chapter is reported a brief summary and review of what emerged from the above-mentioned activities.

2.1.1 Review on key requirements and needs of "Building owners, residents, occupants" and other stakeholders' categories

In this chapter we report a brief summary of the activities carried out and the results that emerged from D1.1.

A first selection of requirements was carried out considering the stakeholders' category of building owners, residents and occupants. The role of this category is of primary importance for the renovation process: building owners, as developers, act as prime movers in the renovation process, deciding to engage in the renovation and residents and occupants are the first interface with renovation works. Speaking about residents and occupants, taking care of their comfort along the renovation process as well as during the use phase of the building is fundamental.

On the basis of the information collected during the first half of Task 1.1 and also on the subsequent performed analysis, a preliminary list of key requirements and needs for the stakeholders' categories from building owners, residents and occupants, has been identified. This first list takes into account three different categories of key requirements and needs:

- "Health, comfort and safety" (HS);
- "Environmental" (EN);
- "Optimized economics" (OE).

Then, an analysis of the key requirements and needs of other stakeholders' categories has been performed. The analysis was based on a desk search, strengthen by the RINNO partners previous experience in the field of deep renovation.

The analysis was carried out taking into account the following other categories:

Table 2-1: List of other considered categories

Category	Description
Designers	The role of designers is to define solutions capable of responding to the building owner's requirements for the renovation process.

	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.[1] As buildings are equipped with more adaptive capabilities (solar shading, secure night ventilation, cross ventilation, buffer zones, etc.) the hardest part for designers and other stakeholders is to attempt a prediction of building performance and to hence an energy usage estimation.
Contractors and subcontractor	Contractors are responsible for the construction works and coordinates subcontractors during the project implementation phases. The needs and requirements of this category are mainly related to a clear understanding of the work schedule and interventions, as well as to communicate with all the actors involved. Contractors have also issues related to the budget and costs of works, as well as the dates of receipt of materials.[2] Other players included in this category are the ESCO Companies and external certification bodies.
Public bodies and administration	Local and public authorities need to oversee renovation projects to monitor adherence to the existing legislative framework, regulations, standards and policies. They need a clear view of the project and the entire renovation process, access to relevant documentation, and direct communication with all parties involved, especially the main contractor.
Industrials	Material and technology suppliers have the role of providing the materials and technical solutions to be adopted by contractors and subcontractors in the renovation project. Material shortage issues lead to major delays in construction projects. Therefore, the materials procurement process must be well implemented, improving the procurement process to avoid delays in supply.[3]
Other	This category includes third parties such as software developers or external consultants, , funders and financial entities and other entities.

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

The final list includes four different categories of key requirements and needs, the first three identified during the analysis of the requirement of the category "building owners, residents and occupant", and a fourth category "General" added in order to cover a wider spectrum of aspects:

1. "Health, comfort and safety" (HS);
2. "Environmental" (EN);
3. "Optimized economics" (OE);
4. "General" (GE).

[1] BUILDUP "Building operation: the elusive alignment of research, design and occupants", available at: https://www.buildup.eu/en/node/57424
[2] 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
[3] AIP Conference Proceedings 2020, 020049 (2018); https://doi.org/10.1063/1.5062675 Published Online: 05 October 2018

Table 2-2. 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 supply performance			X	X		
	R-EN-03	Disaggregation of energy consumption by uses in conditioned spaces			X			
	R-EN-04	Energy uses disaggregation in not conditioned space			X			
	R-EN-05	Total CO_2 emission /reduction			X	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		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 (i. e.. consumables costs)		X	X			
	R-OE-13	Primary activities specific Costs		X	X			
	R-OE-14	Logistics 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-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		X
	R-OE-23	Access to financial subsidies		X	X	X		X
General	R-GE-01	Reduction of project development time	X	X	X			
	R-GE-02	Maintenance cost reduction		X	X			X
	R-GE-03	Resident's comfort improvement			X			
	R-GE-04	CO2 and other pollutant emissions reduction			X	X		X
	R-GE-05	Accuracy of the data gathering of the existing building	X	X		X		X
	R-GE-06	Organization of the documentation	X	X		X	X	X
	R-GE-07	Improvement of the company/body'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				X	
	R-GE-12	Easy interaction with the designer		X	X		X	
	R-GE-13	Easy visualization of the solution	X	X	X	X	X	X
	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

Stakeholders categories								
Key requirements and needs			Designers	Contractors and subcontractors	Building owners, residents and occupants	Public bodies and administrations	Industrials	Others
	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	X			
	R-GE-19	Reduction of number of workers on site		X	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	X			
	R-GE-26	Create best practices	X	X			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	X			X
	R-GE-29	Establishment a degree of interaction between the occupant and the building	X		X			X

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

As mentioned in the first version of this report, the main barriers and challenges encountered during deep renovation project were identified through a detailed review of 31 EU funded projects[4] that deal with state-of-the art deep renovations, running from 2008 up to 2020 (*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*" [5]).

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 Table 2-3.

Through an online questionnaire, all stakeholders have been asked to specify scores 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*). Based on the average scores, Technical and Social barriers and challenges are reported in order of importance.

Table 2-3. Technical, Social and Financial Barriers

#	Technical Barriers
B-TC-01	*End users' and owners' lack of technical expertise and trust in effective energy renovation savings*
B-TC-02	*Lack of consistent and standardized solutions or integrated solutions to comply with new and different building standards requirements on energy saving*
B-TC-03	*Lack of skilled and experienced resources (workers) to carry out the work*
B-TC-04	*Shortcoming in technical solutions and long processes discouraging owners*
B-TC-05	*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*
#	**Social Barriers**
B-SO-01	*Decision-making processes that are long and complex, especially in cases of multi-owner houses (condominiums)*
B-SO-02	*Low awareness about energy efficiency and non-energy benefits of renovation*
B-SO-03	*Lack of consensus, understanding, and support from the inhabitants that often hinder the effective approval of the interventions*
B-SO-04	*Lack of dialogue between the different stakeholders*
B-SO-05	*Problem of disturbance during site works and/or relocation (in case owners/users need to leave their homes during the process)*
#	**Financial Barriers**
B-FI-01	*Lack of attractive financing for homeowners with low to medium incomes who are usually not eligible*

[4] 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)

[5] 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

	for regular bank loans
B-FI-02	*High up-front costs and owners reluctant to borrow funds for energy renovation purposes*
B-FI-03	*Long pay-back times of retrofitting interventions*
B-FI-04	*Lack of confidence of the potential investors*
B-FI-05	*Insufficient and instable available funding*
B-FI-06	*Existing financial tools are insufficient and unattractive*

Financial aspects are among the biggest barriers for building owners and co-owners when it comes to renovations. In this context, return on investment and upfront costs are critical. Moreover, the lack of financing opportunities and/or the inability to obtain financing on acceptable terms is generally one of the most cited barriers to investment in energy efficiency measures.

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[5]. In line with identified barriers, three main categories of challenges are identified, namely *Technical* (TC), *Social* (SO) and *Financial* (FI) challenges (C).

In the context of innovative deep renovation, it is more crucial to understand what is relevant when it comes to technological aspects for end users, including how property owners perceive technological changes and how they evaluate their benefits and potential drawbacks.

The complete list of identified Challenges is reported in the following Table 2-4.

Table 2-4. Technical, Social and Financial Challenges

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

The analysis and identification of barriers and challenges performed during the first part of the project has been validated along the project.

2.2 RINNO Key Requirements and KPIs

In this paragraph, a final list of RINNO Key Requirements is presented.

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. This analysis is briefly reported in this deliverable (chapter 2.1) but is addressed in detail in D1.1.
- An online questionnaire, shared within the building renovation process stakeholders, 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. A deep analysis of this online questionnaire is present in the first version of the deliverable (D1.1).
- Analysis of synergies within WP1 RINNO to define a preliminary list of KPIs for evaluating the performance of RINNO technologies/solutions during project evolution from technical, economic, environmental, and social perspectives.

The list of RINNO key requirements have been considered in the selection of KPIs for Deliverable 1.7 "*Report on RINNO KPIs (Final Version)*", to take into account the renewal needs and requirements of stakeholders.

In the above-mentioned deliverable, a list of KPIs is proposed and an analysis in terms of relevance for the Key Requirements is performed. In

Table 2-5 the final list of the Key requirements is reported, revised based on the considerations made during the KPI analysis.

Table 2-5. RINNO Key Requirements

Category	RINNO Key Requirements	KPI	Explanation	Relevant Phases in the Renovation Process
TECHNICAL ASPECTS	Increased energy savings	Yearly primary energy savings [kWh/(m2year)]	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 the main RINNO key requirements since RINNO is looking towards NZEB and even Positive Energy Buildings (PEB), 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)	Space saved [m3]	Literature analysis confirmed that space saving is an 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	*Key requirement not considered in the list of KPIs*	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	*Key requirement not considered in the list of KPIs*	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

Category	RINNO Key Requirements	KPI	Explanation	Relevant Phases in the Renovation Process
	Installation time/costs/workforce saved (reduction of delivery, construction, design and installation time)	Duration of works [h]*	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
	Energy from renewable sources	Yearly degree of self-supply by RES [%]	The analysis of the questionnaire has indicated the importance of increasing the levels of energy efficiency and/or decreasing energy consumption, for example, by integrating cleaner energy sources and even using 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.
ECONOMICAL ASPECTS	Life cycle cost savings/reduction	Life Cycle cost savings [€]	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	Return on Investment [%]		Planning and design phase
	Payback period	Payback period [years]		Planning and design phase
	Installation time/costs/workforce saved (reduction of delivery, construction, design and installation time)	Cost savings in design [€, %]* Reduction of cost overruns [€, %]* Reduction in construction cost [€, %]* Savings in material cost [€, %]*	Described in the Technical aspect	

Category	RINNO Key Requirements	KPI	Explanation	Relevant Phases in the Renovation Process
ENVIRONMENTAL ASPECTS	Environmental Life cycle GWP savings/Reduction of the greenhouse gases emissions and/or air pollutants	Yearly life cycle GWP savings [kgCO2eq/m2year] Yearly embodied energy savings [MJ/(m2year)] Yearly water footprint savings [l/(m2year)]	Literature analysis and questionnaire analysis have highlighted that environmental life cycle by reducing Greenhouse Gases (GHG) emissions 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, and therefore, to the decarbonization and the reduction of GHG in buildings.	Planning and design, construction/renovation and monitoring/operation renovation stages.
MATERIALS	Use of bio-based materials	Use of bio-based materials [kg, %]*	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[6]. 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
	Use of recyclable and recycled materials	Use of recyclable materials [kg, %]*[7] Use of recycled materials [kg, %][8]		
	Reduce use of raw materials (Material use avoided)	Material use avoided [kg, %]*		
	Waste Reduction	Waste production [kg]		

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

[7] "*Use of bio-based materials*" and "*Use of recyclable materials*" are considered more relevant at technology/product level than at renovation route level. Potential use in the calculation of project impacts (WP6) and in "material passport" (WP7). Source of information: WP2

[8] considered relevant also at technology/product level, but this information is already available at planning and design stage, from LCA databases and WP2 information. Therefore, it is included as environmental indicator, also given the increasing importance given to the use of recycled materials. Potential additional use in the calculation of project impacts (WP6) and in "material passport" (WP7). Source of information: WP2.

Category	RINNO Key Requirements	KPI	Explanation	Relevant Phases in the Renovation Process
SOCIAL ASPECTS	Acoustic insulation improvement	*Key requirement not considered in the list of KPIs*	**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 aimed at address this requirement. 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.	Monitoring/operation renovation stages
	Indoor Air quality improvement	Time outside Indoor air quality range [h]*		Monitoring/operation renovation stages
	Thermal Comfort improvement	Time outside thermal comfort range (h)*		Monitoring/Operation renovation stages.
	No need for the resident to leave the building during the works	*Key requirement not considered in the list of KPIs*	**Residents' comfort during the renovation process:** 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.
	Time reduction on site (reduction of visits on site)	Time reduction on-site [h]*		
	Reduction of number of workers on site	*Key requirement not considered in the list of KPIs*		
	Integration of requests from residents	*Key requirement not considered in the list of KPIs*		

Category	RINNO Key Requirements	KPI	Explanation	Relevant Phases in the Renovation Process
	Degree of discomfort of the occupants	*Key requirement not considered in the list of KPIs*		
	Reduction of accidents/ unforeseen event on site	*Key requirement not considered in the list of KPIs*	**Site quality improvement**: 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.
	Easy collaboration with other stakeholders			
	Easy collaboration with client/supplier			
	Complaint management improvement			
	Management of the material on site			

**Not included in the final list of KPIs included in D1.7 because the list is used to evaluate and identify the best renovation scenario and not only technology technical aspects.*

2.3 Main recommendations and suggestions from demo cases

This chapter briefly reports the outcomes of activity T1.3 "Pilot Sites Surveys & Definition of Use Case Renovation Scenarios," whose results are presented in deliverable D 1.4 "RINNO Pilot Analysis and Deployment Plan", with the aim to extract relevant recommendations and suggestion for the final set of requirement definition.

This task aims to draft the preliminary renovation scenarios related to the demo cases, based on the results of the surveys and occupant needs analysis.

In fact, a list of goals reachable through the renovation process has been identified and, for each demo case, residents were asked to prioritize the objectives.

Here below are reported the characteristics of the buildings used for the different demo cases. The priorities associated by the residents to the list of objectives will then be compared in order to carry out a matchmaking between the objectives considered to be of higher importance and the key requirements defined and reported in the previous chapter.

2.3.1 Demo buildings overview

Greek demo

This pilot building is a 4-floor, 2-apartment for each floor of 75sqm, with concrete frame structure and hollow brick infill, built in 1970. It has no systems to reduce energy consumption, either for heating or cooling, it has a shell with low thermal resistance and low inertia, thus inadequate to provide the necessary thermal phase shifting and attenuation during the summer season.

Windows are equipped with aluminium frames, with no thermal break, and single glazing, while the external shutters are sliding or rolling blinds, which do not allow light to be adjusted according to solar radiation at different times of the day.

Figure 2-1: Greek demo building

The building presents several external degradation factors:

- Different shutters in different maintenance state;
- Presence of air conditioners and cables, with their associated occurrence of significant holes, disposed without any specific criteria;

- Disordered distribution of solar collectors on the roof.

The building presents several other signs of deterioration, including deterioration of plaster around windows and plaster peeling from balconies, and traces of staining due to rainwater runoff caused by the lack of proper gutters.

Polish demo

The Polish demonstrator is a detached building of traditional load-bearing masonry, built in 1949, with three floors above ground and a semi-basement level on the north side. It is 12 meters high and consists of 5 flats accessible through a central unheated staircase.

Figure 2-2: Polish demo building

Each apartment is heated by stoves fed manually with coal (in pieces and powder), pellets and wood.

The natural ventilation system is inefficient. Both the envelope walls and the partition walls with the attic, stairs, and other unheated rooms lack insulating layers.

The walls are made of solid bricks of varying thicknesses of one, two and three blocks and have high transmittance values; therefore, they are unable to provide an adequate level of thermal insulation.

The ceiling of the basement consists of a concrete slab without insulating layers, and the floor of the remaining part of the ground floor consists of concrete slabs on brick rubble.

French demo

This building was built in 1976, consists of 5 floors, and is divided into 6 small apartments per floor, each with a single large window on the east or west side that are ineffective not only in terms of thermal insulation but also with regard to acoustic performance. The north and south fronts are completely blind.

Figure 2-3: French demo building

The heating system is centralized and is through a natural gas boiler, located in the boiler room, but emits heat at excessively low temperatures. As for the envelope, both the walls and the roof have a low level of insulation.

Danish demo

The building that has been used for this demo is a linear building of more than 200 meters in length and 10 floors in height that includes about 464 apartments.

The original design included the presence of balconies on both the east and west sides, which were enclosed by glazed facade modules during a renovation carried out in 1988. During this renovation, a solar thermal system was installed on the roof and integrated to the District Heating Network.

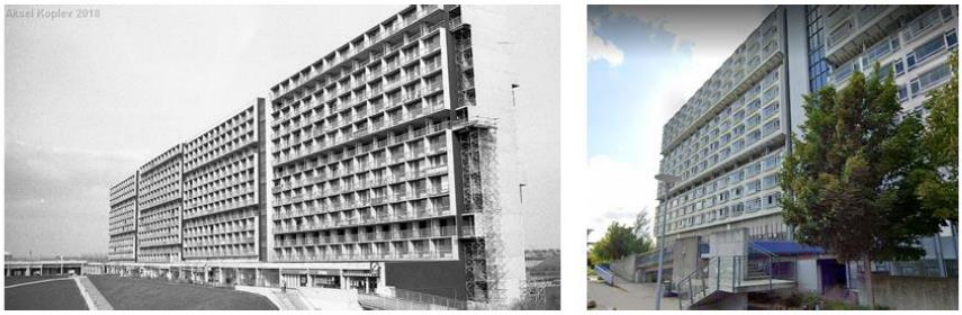


Figure 2-4: Danish demo building

2.3.2 Comparison of objectives prioritization

A list of 15 goals achievable through the deep renovation process was shared with residents of the various buildings described above. Residents were asked to rate the importance of the goals on a scale of from 1 to 5 (*1 = not important; 5 = very important*) in order to obtain a prioritization table.

This section aims to compare the priorities found in the different building types to understand what the common elements and the main differences may be.

The table below shows the priorities found for the different demo cases.

Table 2-6: Prioritization matrix

		Objectives that can be achieved through a renovation process	Greek Demo	Polish Demo	French Demo	Danish Demo
ENERGY-RELATED	1	Heating cost savings	**5**	**5**	**5**	**5**
	2	Cooling cost savings	5	2	2	1
	3	Lighting cost savings	3	5	2	3
ECONOMICAL	4	Minimization of renovation time	5	4	4	3
	5	Minimization of renovation costs	4	4	5	4
	6	Maintenance cost reduction	4	4	5	3
SOCIAL	7	Eco-Labelling	4	3	3	4
	8	Residents' Comfort	**5**	**4**	**5**	**4**
	9	Better air quality	5	5	3	4
	10	Building life extension	5	3	5	4
	11	Building aesthetics enhancement	3	3	4	4
	12	Lower noise level	4	2	3	4
ENVIRON-MENTAL	13	Minimization of waste production	4	2	4	2
	14	Carbon footprint	5	3	5	4
	15	Eco-friendliness	**4**	**4**	**5**	**4**

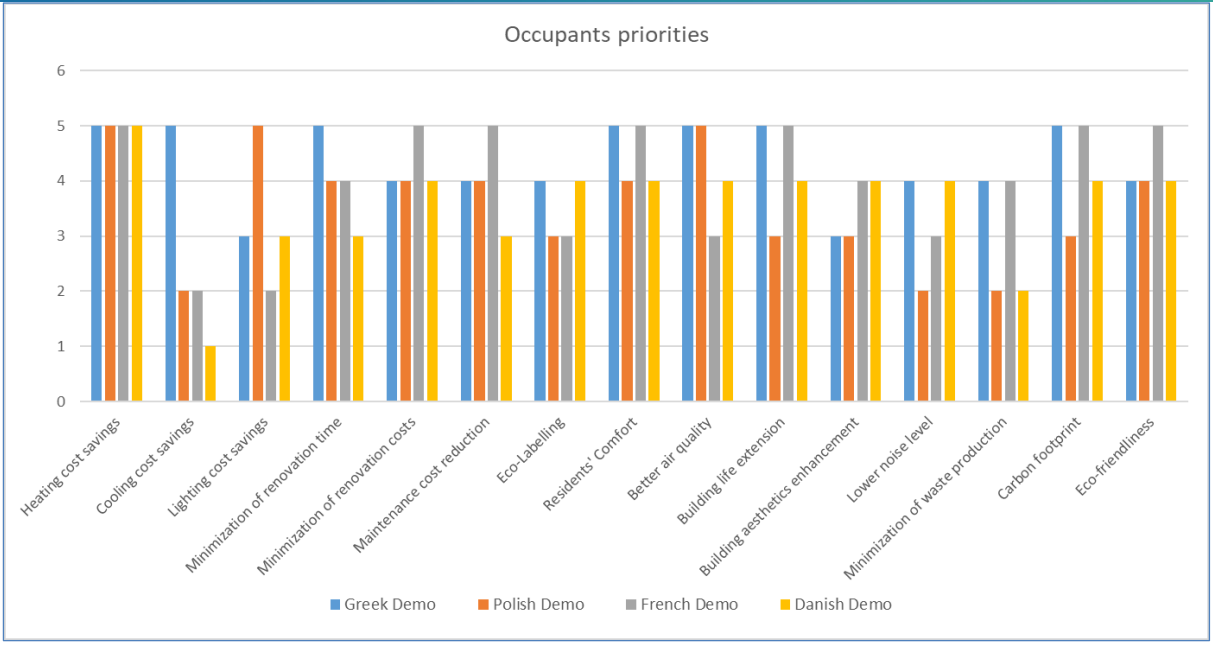


Figure 2-5: Comparison of the priorities

By comparing the priority associated with the goals by the residents of the different demo cases, it is possible to see that some are relevant to most of the occupants. Specifically, an average of the values associated by the residents of the different demo cases was calculated, and it was identified which goals are the most important, dividing them according to the defined categories, respectively "*Energy-related*", "*Economical*", "*Social" and "Environmental*".

The table below shows the average priority values of the objectives.

Table 2-7: Average priority

		Objectives that can be achieved through a renovation process	Average priority
ENERGY-RELATED	1	**Heating cost savings**	**5**
	2	Cooling cost savings	2,5
	3	Lighting cost savings	3,25
ECONOMICAL	4	Minimization of renovation time	4
	5	**Minimization of renovation costs**	**4,25**
	6	Maintenance cost reduction	4
SOCIAL	7	Eco-Labelling	3,5
	8	**Residents' Comfort**	**4,5**
	9	**Better air quality**	**4,25**
	10	**Building life extension**	**4,25**
	11	Building aesthetics enhancement	3,5
	12	Lower noise level	3,25
ENVIRON-MENTAL	13	Minimization of waste production	3
	14	**Carbon footprint**	**4,25**
	15	**Eco-friendliness**	**4,25**

Figure 2-6: Most important objectives

Based on the scores associated by all the occupants, the most important energy-related objective is "*Heating cost saving*", this is due to the energy inefficiency of today's buildings, which, having high thermal transmittance values make it necessary to expend a great effort to adequately heat spaces.

Regarding the economic objectives, the one considered most important is "*Minimization of renovation costs*". Indeed, it appears to be a priority for residents that the necessary interventions to increase the building's energy efficiency should not have high costs, and therefore solutions with the right cost/efficiency ratio are preferred.

The social objectives considered most important are "*Residents' Comfort*", "*Better air quality*" and "*Building life extension*". For example, currently air quality may be inadequate due to the presence of coal-fired stoves and the lack of adequate ventilation.

In terms of environmental impact aspects, the objectives that are considered most relevant are "*Carbon footprint*" and "*Eco-friendliness*".

3 RINNO Technologies/Solutions Catalogue and Roadmap to TRL 9

Within this chapter, a deep analysis of the technologies/solutions proposed by RINNO project partners have been carried out trying also to summarise the RINNO Technologies/Solutions Catalogue. The last one, in particular, is aimed at populating 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 in this activity are analysed to establish a link between the RINNO requirements and the above-mentioned needs and technologies.

The main outcomes of this section are a more detailed description of the RINNO Technologies/Solutions and a TRL assessment in order to define a TRL 9 Roadmap.

3.1 RINNO Technologies/Solutions Catalogue

In this final version of "*RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL 9*" the technologies/solutions proposed by the project partners have been detailed with a sort of catalogue aimed at summarizing the technology key points, such as:

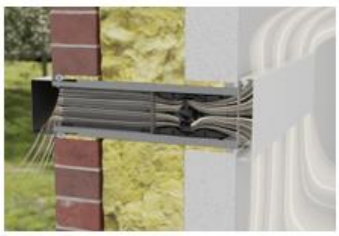
- Technology brief description;
- Innovative content;
- Target market;
- Market maturity;
- Potential customer;
- Main potential competitors;
- Unique value proposition.

The catalogue presented in the next sections is part of the RINNO Renovation Repository (RRR).

3.1.1 MicroVent – Sustainable Ventilation (In Ventilate – EKOLAB)

Table 3-1: MicroVent Technology/Solution Characterization

CHARACTERIZATION TABLE	
TECHNOLOGY TITLE	MICROVENT
Leader Partner Name	EKOLAB
Short Company profile	InVentilate develops and delivers energy-saving decentralized ventilation for the benefit of the climate and economy
Company website	www.inventilate.dk




Technology Short description

MicroVent is a facade integrated ventilation system with the lowest power consumption in the market; the electricity consumption is only 0,083 Wh/m3. The ventilation system recovers around 80-92% of the heat, depending on the air exchange level.

The MicroVent system consists of a minimum of two units working together; one unit removes air while the other supplies fresh air. Then it reverses. Every unit has a regenerative heat exchanger that accumulates the heat from the exhaust air and then releases it when the air flow is reversed.

The ventilation system is demand-controlled with variable air volume (VAV) based on CO2, temperature, and relative humidity. MicroVent is installed directly in the facade and can ideally be combined with window replacement. The minimal space requirements provide freedom of design and significant cost reduction both during installation and operation. For renovation projects, MicroVent provides a solution for ventilation, when there is a lack of space for traditional air ducts or when you prefer a less invasive solution.

It is a patented intelligent control system, which enables units' collective response to ambient changes, reducing power consumption while optimizing user-comfort.

Innovation content

Innovative content of MicroVent

- Wind pressure measurements integrated for improved comfort and a more intelligent control system (wind compensation)
- Optimized interaction between units and the kitchen cooker hood
- Option of filters
- Easier installation
- Cloud solution, with an overview of the systems, with insight into operating mode and the possibility of control from a computer or telephone online. The cloud solution also gives the possibility to configure the system online, with support from InVentilate in Denmark

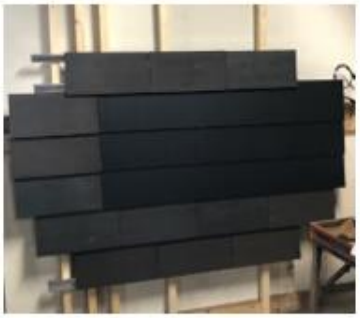
MARKET POTENTIAL	
Sector(s) of application	Institutions, schools, offices, and residential
Expected Time to Market at the end of the project	The advancements are expected to be ready for the demonstration on pilots in summer 2022.
Target Market	Institutions, schools, offices and residential - including multi-story apartments
Market size and relevant trend:	The product is relevant for a large part of the building mass.
Market maturity: The market for this result is…	☐ Not yet existing: customers are not buying such products (or are not yet ready to buy such products/services) ☐ Emerging: There is a growing demand and few offerings are available. (In commercial real estate few offerings are available, but in housing real estate not) ☒ Mature: The market is already supplied with many products of the type proposed (But only in Denmark)
Potential customers	The product addresses customers in need for a simple ventilation solution, and who considers sustainably.
Potential end users (if different from customers)	The product addresses customers in need for a simple ventilation solution, where the facade is well suited for the ventilation systems aesthetics, saving indoor space and energy.
Potential main competitors	Duka One, for residential (a low-cost solution on the Danish market - our solution is a more high-end) Airmaster for institution, schools, and larger offices. Also, central/decentral ventilation with ducts
Unique value proposition (against competitor's solutions)	Most energy efficient solutions on the ventilation market. Because of the unique construction and fan solution it is a very quiet system compared to competitors.

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 building. Minimal space requirements. Residents/Tenants/Occupants: Improved indoor climate with lower CO2 level, and better temperature control. Reduced heat consumption due to heat recovery from ventilation. Reduced electricity consumption when compared to other ventilation system, i.e., central ventilation with many ducts.

3.1.2 Kompromenť PV-Roof and Facade solutions (EKOLAB)

Table 3-2. Kompromenť PV-Roof and Facade Technology/Solution Characterization

CHARACTERIZATION TABLE	
TECHNOLOGY TITLE	**ZAPPA INTEGRATED PV FACADE SOLUTION**
Leader Partner Name	EKOLAB
Short Company profile	Kompromenť delivers external climate cover for building. Their environmentally aesthetic roof- and facade solutions protect any building against the elements. The combination of unique mounting systems along with a wide range of natural materials creates durable and beautiful roofs and facades.
Company website	www.kompromenť.com – www.kompromenť.dk


Technology Short description

Zappa is a universal envelope for facades, that incorporates natural slate and PV. The PV modules replaces ordinary wall and roof materials, which makes these solutions more economic than add-on PV solutions.

The advantage of the technology is:

- Energy productive facade
- A lightweight climate screen
- PV is integrated with a long lasting, no maintenance, natural slate material

An easy and quick assembly/disassembly time

Innovation content

The main innovations to be conducted during RINNO project are:

- Reduction of costs in assembly systems
- Replacement of aluminium battens and hooks with stainless steel
- Localization of better price / performance on PV

Innovative content

- Designed for disassembly
- Cradle to cradle certified (slate)
- BIPV with superior aesthetics

MARKET POTENTIAL	
Sector(s) of application	Commercial, Residential
Expected Time to Market at the end of the project	The product has finished and is ready for sales in Denmark. The product is now looking at the German market to make it ready for export.

Target Market	Commercial, Residential
Market size and relevant trend:	The product is relevant for the most part of the building sector
Market maturity: The market for this result is…	☐ Not yet existing: customers are not buying such products (or are not yet ready to buy such products/services) ☐ Emerging: There is a growing demand, and few offerings are available. (In commercial real estate few offerings are available, but in housing real estate not) ☒ Mature: The market is already supplied with many products of the type proposed
Potential customers	The product addresses customers interested in cradle-to-cradle principals and customers seeking aesthetically better integrated PV solutions.
Potential end users (if different from customers)	-
Unique value proposition (against competitor's solutions)	• Integrated in a program of façade solutions • The façade is energy productive • The PV part and the façade is designed to have similar appearance, improving the overall aesthetics • The energy productive part replaces equal amount of façade material, as it is not an add-on PV solution
Benefits to Building owner/residents/tenants/occupants or other stakeholder group in the renovation value chain	Building owners: The building may experience added value due to a better aesthetical design compared to conventional PV façade systems and the cradle-to-cradle materials may add signal value to the building. Low maintenance and durability save ongoing costs. Residents/Tenants/Occupants: A pleasing aesthetical design and energy savings from the energy production

3.1.3 Isocell Cellulose Insulation (EKOLAB)

Table 3-3. Isocell Cellulose Insulation Technology/Solution Characterization

CHARACTERIZATION TABLE	
TECHNOLOGY TITLE	ISOCELL CELLULOSE INSULATION
Leader Partner Name	EKOLAB
Short Company profile	Nviro CBI Papiruld A / S is Denmark's strongest supplier of insulation solutions for sustainable construction. The insulation product portfolio can be used for ceilings, cavity walls, roofs, floor separations and crawl spaces.
Company website	https://nviro.dk/produkter/isocell/
	
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 during 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
Expected 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
Market maturity: The market for this result is…	☐ Not yet existing: customers are not buying such products (or are not yet ready to buy such products/services) ☐ Emerging: There is a growing demand, and few offerings are available (in commercial real estate few offerings are available, but in housing real estate not) ☒ Mature: The market is already supplied with many products of the type proposed
Potential customers	The product addresses customers interested in a more environmentally friendly quality insulation product
Potential end users (if different from customers)	Building occupants
Unique value proposition (against competitor's solutions)	It is made from surplus newspapers
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. Higher building value. Residents/Tenants/Occupants: Heat consumption bill is reduced

3.1.4 Bio-based materials (K-FLEX POLSKA)

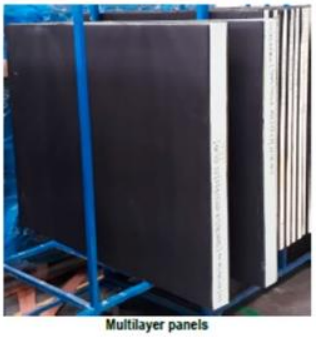
Table 3-4. Bio-based materials Technology/Solutions Characterization

CHARACTERIZATION TABLE	
TECHNOLOGY TITLE	BIO-BASED MATERIALS
Leader Partner Name	K-FLEX
Short Company profile	K-FLEX is a multinational manufacturing company specialised in the production of thermal and acoustic flexible elastomeric insulation materials. The company has production facilities and a network of subsidiaries around the globe in order to provide its products and services to customers wherever they are in the world. Its diversified product portfolio provides cutting-edge solutions for many sectors including constructions, transportation, petrochemical and renewable energy industry. For over 30 years K-FLEX products have been recognized on the insulation market for their high standards of INNOVATION, QUALITY and PERFORMANCE that play an essential role in the energy consumption control and the reduction of GHG.
Company website	https://kflex.com/

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:

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

The products are the following:

1. Bio-based double layer panels with bio-based (25-50%) polyurethane and compact rubber for insulating panels.
2. 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.
3. K-BOX bio-based insulating system for the pipes of HVAC systems, PVs and Solar Panels.

Bio-based double layer panels - Insulation panels made from PUR foam and solid SBR based rubber are highly efficient thermal and acoustic insulation material. Materials for this composite are producing in two separate processes and at the end PUR foam and SBR based rubber are connected by gluing. These materials are characterized by high fire resistance and wide range of temperatures in which they can be used.

Pipes and sheets based on EPDM - Highly efficient thermal insulation material. There are produced with addition of

blowing agents which are creating rubber foam during vulcanization process. These materials are characterized by high fire resistance and wide range of temperatures in which they can be used. Additionally, rubber composite from which they are made contain a high percentage of bio-based content.
K- BOX - Pre-formed insulation boxes suitable for the insulation of valves, filters, flanges and other components in the piping system. Each component has been specially designed to fit perfectly with the insulated equipment. The elastomeric closed-cell structure provides very low thermal conductivity combined with excellent water vapor diffusion resistance.

Innovation content

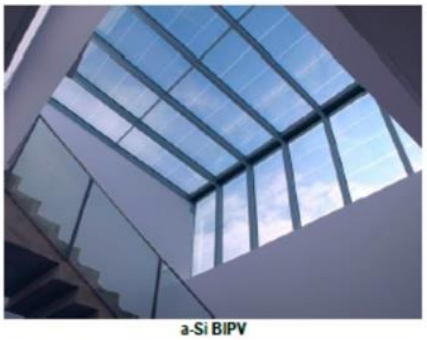
Main Innovations to be conducted in the course of RINNO:

- The new EPDM material realized with bio-based raw material and increased fire resistance properties, will be realized and demonstrated during the instalment of the various systems. New type of EPDM composite is innovative due to the use of new type of EPDM elastomer characterized by high percentage of bio-based content. EPDM composites are extremely sensitive for any changes in raw materials or production parameters. Change of polymer matrix caused many changes in both the composition and production technology. Final product has the same properties and price as the one made of standard EPDM.
- The new doble-layer panels that will merge high thermal insulation properties with sound absorption are produced from raw materials with high percentage of bio-based content. The new polyol forced the production line to be changed in order to have more control over the process (temperature, speed, etc.)
- K-BOX is expected to achieve a reduction of installation time by roughly 95 percent. K-BOX is extremely easy plug and play system. Is designed this way to make installation as simple as possible. Only difficulty is in order proper K-BOX to proper valve, filter, flange or other components in the piping system. Installer have to open K-BOX from one side which is properly design, cover component in piping system and close K-BOX.

MARKET POTENTIAL	
Sector(s) of application	Building insulation and building HVAC systems
Expected Time to Market at the end of the project	After tests in demo buildings products may be avaible
Target Market	Building industry
Market size and relevant trend:	Whole world building industry. Specially now, when the save of energy is so important
Market maturity: The market for this result is…	☐ Not yet existing: customers are not buying such products (or are not yet ready to buy such products/services) ☐ Emerging: There is a growing demand and few offerings are available. (In commercial real estate few offerings are available, but in housing real estate not) ☒ Mature: The market is already supplied with many products of the type proposed
Potential customers	Companies involved in the design and/or construction of HVAC systems and buildings insulation
Potential end users (if different from customers)	Residents of the buildings where these products have been installed
Potential main competitors	Armacell, Kaimann
Unique value proposition (against competitor's solutions)	The development of these products was possible thanks to a modern and well-equipped (with equipment and people) laboratory. In addition, K-Flex is currently a leader in the production of highly effective thermal insulation. K-FLEX employees have extensive experience in developing innovative products which very complex composition (over 20 different ingredients) makes it very difficult to copy or imitate them.
Benefits to Building owner/residents/tenants/occupants or other stakeholder group in the renovation value chain	These products are increasing energy efficiency thanks to low value of thermal conductivity and reduction of annual energy costs for end-users is possible

3.1.5 Building integrated Photovoltaic glass (GREENSTRUCT)

Table 3-5. Building integrated photovoltaic glass Technology/Solution Characterization

CHARACTERIZATION TABLE	
TECHNOLOGY TITLE	BUILDING INTEGRATED PHOTOVOLTAIC GLASS
Leader Partner Name	GREENSTRUCT
Short Company profile	GREENSTRUCT is a Technical Commercial company. The main operational axis lies in establishing a key enterprise network focused primarily on collaborating with some of the most innovative companies worldwide, leading their industry.
Company website	www.greenstruct.gr
 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 during RINNO will be the creation of a prefabricated aluminium 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
Expected 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. The module is ready for installation right now.
Target Market	Commercial buildings large scale mostly
Market size and relevant trend:	The global building integrated photovoltaics market was valued at 14 billion dollars in 2020 and is projected to reach 87 billion US dollars by 2030, growing at a CAGR of 20.1% from 2021 to 2030.

Market maturity: The market for this result is…	☐ Not yet existing: customers are not buying such products (or are not yet ready to buy such products/services) ☒ Emerging: There is a growing demand and few offerings are available. (In commercial real estate few offerings are available, but in housing real estate not) ☐ Mature: The market is already supplied with many products of the type proposed
Potential customers	Building owners, Architects, Developers
Potential end users (if different from customers)	Building owners
Potential main competitors	Regular photovoltaic panels manufacturers and installers
Unique value proposition (against competitor's solutions)	This is a system that can be installed on building façade and every other surface that a typical glass can be installed. Regular photovoltaic panels can be only installed on rooftops.
Benefits to Building owner/residents/tenants/occupants or other stakeholder group in the renovation value chain	The use of this technology has the following advantages: - 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; - high amounts of energy production; - Reduced needs of maintenance.

3.1.6 Thermochromic glass (GREENSTRUCT)

Table 3-6.Thermochromic Glass Technology/Solution Characterization

CHARACTERIZATION TABLE	
TECHNOLOGY TITLE	**THERMOCHROMIC GLASS**
Leader Partner Name	GREENSTRUCT
Short Company profile	GREENSTRUCT is a Technical Commercial company. The main operational axis lies in establishing a key enterprise network focused primarily on collaborating with some of the most innovative companies worldwide, leading their industry.
Company website	www.greenstruct.gr
 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.	

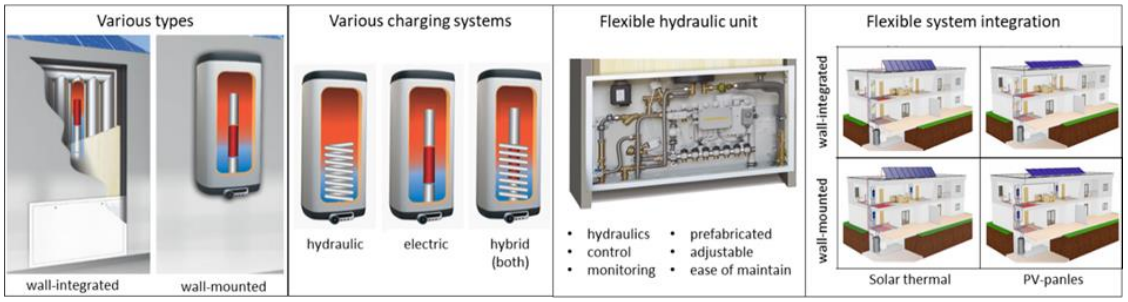
Innovation content Up until now every glass surface in a building had a standard tint or no tint at all resulting in fixed technical properties such as G value, solar heat gain coefficient etc. This means that if we want to have a well-insulated glass surface, we must use a very dark tinted glass in 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
Expected 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 aluminium modules ready to be installed in the building as well as monitor all the internal space variables concerning energy conservation and comfort. The product is ready for installation and market.
Target Market	Commercial and residential buildings
Market size and relevant trend:	The global electrochromic glass market was valued at $1.4 billion in 2019 and is projected to reach $2.6 billion by 2027, growing at a CAGR of 9% from 2020 to 2027.
Market maturity: The market for this result is…	☐ Not yet existing: customers are not buying such products (or are not yet ready to buy such products/services) ☒ Emerging: There is a growing demand and few offerings are available. (In commercial real estate few offerings are available, but in housing real estate not) ☐ Mature: The market is already supplied with many products of the type proposed
Potential customers	Building owners, Architects, Developers
Potential end users (if different from customers)	Building occupants
Potential main competitors	Pleotint, Qingdao Morn Building Materials, Vario Glass
Unique value proposition (against competitor's solutions)	This technology allows the sun heat to enter inside the building during winter and autumn, while it is able to heat it up properly and rejecting the sun heat in summer creating a building that is self-regulated in terms of energy allowance and rejection.
Benefits to Building owner/residents/tenants/occupants or other stakeholder group in the renovation value chain	By using thermochromic glasses instead of regular glasses, the building can regulate itself the amount of sun energy entering inside and cut off the excessive heat in summer months while allowing at the same time the external view.

3.1.7 De-centralized domestic hot water preparation (PINK)

Table 3-7. De-centralized domestic hot water preparation Technology/solution Characterization

CHARACTERIZATION TABLE	
TECHNOLOGY TITLE	**DE-CENTRALIZED DOMESTIC HOT WATER PREPARATION**
Leader Partner Name	PINK
Short Company profile	The company Pink GmbH has years of experience in the field of the design and production of storage tanks, stainless steel hot water tanks and energy storage tanks.
Company website	www.pink.co.at



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.
- Prefabricated 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 during 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
Expected 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). For the standard version of the product, the TRL 8-9 has already been achieved. For necessary product adjustments and improvements of individual components the TRL 9 should be achieved within the remaining two years. Only for the bio-based insulation of the wall mounted storage tank at the end of the project the TRL 7 should be reached, so a demo application is intended.
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).
Market maturity: The market for this result is…	☐ Not yet existing: customers are not buying such products (or are not yet ready to buy such products/services) ☐ Emerging: There is a growing demand and few offerings are available. (In commercial real estate few offerings are available, but in housing real estate not) ☒ Mature: The market is already supplied with many products of the type proposed
Potential customers	• Construction companies Due to the distribution structure, the only customers who purchase Pink's products are the construction companies, which do the actual construction work. Thereby the company sizes can range from small plumbers to large building contractors. However, the actual product decisions are usually not made by these construction companies, but it is mostly done by: • Engineering companies • Designer and Architects • Housing associations Therefore, these companies are also comprehensively supported in the planning process, even they finally do not buy any products from the Pink company.
Potential end users (if different from customers)	• Building owner • Resident homeowner • Housing associations
Potential main competitors	Due to the fact that decentralized domestic hot water tanks are a standard product that has been in use for a very long time, there is a very large number of competitors on the market for standard DHW-storage tanks.
Unique value proposition (against competitor's solutions)	The product of the wall-integrated tank with its flat and therefore space-saving design differs significantly from the conventional hot water tanks available on the market. In addition, the extended area of activity, which includes not only the actual storage tank but also other important fields of domestic hot water supply and the heating and/or cooling of buildings, can be mentioned as a unique selling point. This holistic view of the energy supply system is illustrated by the availability of the following additional products: • Different charging systems • Flexible hydraulic units • Optimized control systems
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 through 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

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

In the following paragraph, an assessment of RINNO technologies/solutions (9 products) was performed aiming at the 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. The analysis performed in the first version of this deliverable has been updated, with particular focus on the key requirement list.

As shown in Table 3-8, 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 still uncovered by the innovative solutions proposed, however, these requirements are mainly focused on the market, stakeholders' interaction, installation and operation procedures and are not directly related to technical aspects.

Table 3-8. 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)
Increased 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									
Environmental Life cycle GWP savings/Reduction of the greenhouse gases emissions and/or air pollutants	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
Reduce use of raw materials (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 Insulation Improvement	X		X	X	X	X		X	
Space saving (less invasive solutions)	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 and justification of the decision making process	X	X	X						
Complaint management Improvement									
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									
Degree of discomfort of the occupants									
Management of the material on site									

3.3 TRL Assessment and Roadmap to TRL9

The final goal of this work is to perform a TRL (*Technology Readiness Level*) assessment in order to define a technological roadmap for each RINNO innovative solutions, and to draft pathways for technology development aiming to bring the RINNO technologies/solutions to their full commercialisation potential.

The roadmapping activities have been based on the information collected through a dedicated questionnaire and reported in the present document. Starting from the identified technologies, with reference to the main requirements as well as the barriers and challenges identified, the main R&D barriers and challenges have been detected and included in the roadmap.

An example of a graphic representation of the roadmap is shown in Figure 3-1

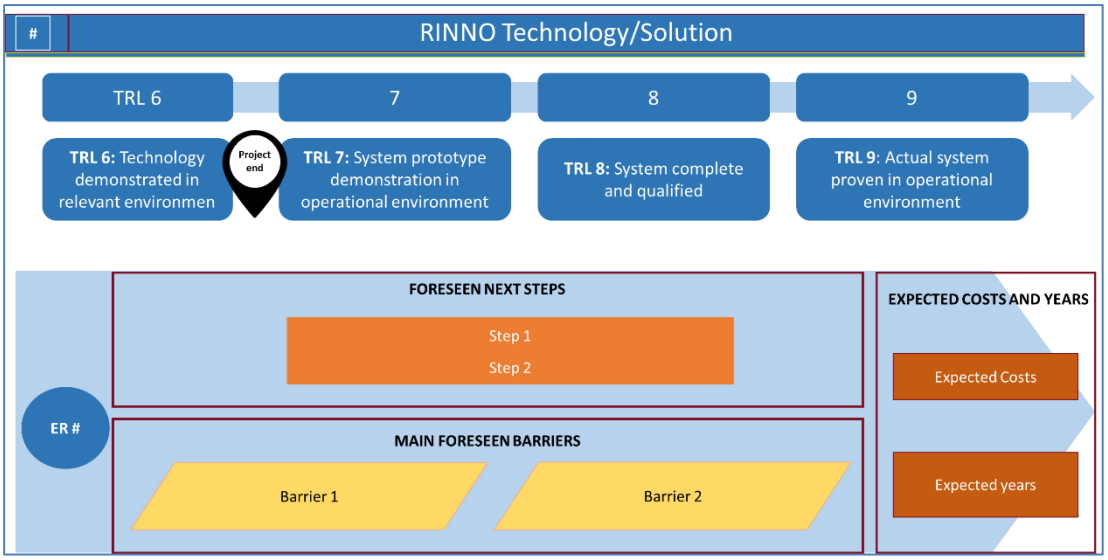


Figure 3-1: Example of TRL 9 Roadmap graphic representation

Special attention has been reserved to technological aspects. A detailed assessment on the current status of technology development has been 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 reach TRL 9.

Being a public report, some confidential information was not included in the tables and roadmaps below. Such information is reported in ANNEX 1. of the confidential version of the present report.

The technological roadmap of development is based on the Technology Readiness Level definition, reported in the

Table 3-9 below.

Table 3-9: TRL description

TRL Level	TRL Title	TRL Level description
1	Basic principles observed	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include fundamental investigations and paper studies
2	Technology concept formulated	Once basic principles are observed, practical applications can be formulated. Examples are limited to analytic studies and experimentation.
3	Experimental proof of concept	Active research and development is initiated. Laboratory studies aim to validate analytical predictions of separate components of the technology. Examples include components that are not yet integrated or representative.
4	Technology validated in lab	Design, development and lab testing of technological components are performed. Here, basic technological components are integrated to establish that they will work together. This is a relatively "low fidelity" prototype in comparison with the eventual system.
5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)	The basic technological components are integrated together with realistic supporting elements to be tested in a simulated environment. This is a "high fidelity" prototype compared to the eventual system.
6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)	The prototype, which is well beyond that of level 5, is tested in a relevant environment. The system or process demonstration is carried out in an operational environment.
7	System prototype demonstration in operational environment	Prototype is near, or at, planned operational system level. The final design is virtually complete. The goal of this stage is to remove engineering and manufacturing risk.
8	System complete and qualified	Technology has been proven to work in its final form under the expected conditions. In most of the cases, this level represents the end of true system development.
9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)	Here, the technology in its final form and is ready for commercial deployment.

3.3.1 MicroVent – Sustainable Ventilation (In Ventilate – EKOLAB)

The integrated ventilation system with low power consumption (*MicroVent*) developed by EKOLAB is currently ad TRL 9. During the project, different R&D activities have been performed in order to reach this result.

The following table shows the data needed to conduct a TRL assessment and to design a TRL roadmap. In particular, the questionnaire and the roadmap contain the activities carried out within the project to achieve these results, the main foreseen barriers and challenges to obtain what is intended to be achieved within the project and an indication of expected costs.

Table 3-10: MicroVent TRL 9 Roadmap questionnaire

QUESTIONNAIRE
1. Which is the actual Technology Readiness Level (TRL) of the technology "MICROVENT"? Please provide further information about all the activities that you performed so far during the Project.
The product has upgraded from TRL8 – TRL9 by performing the following activities during RINNO, since June 2020: • New electronics with wireless communication • Software update with optimized wind compensation • Optimized management for replacement air for the cooker hood • Sound-absorbing solutions for external noise and fan noise • New interior and exterior covers in a more elegant design and easier for installation and service. • New solutions (MicroVent box, MicroVent wall and MicroVent Window)
2. Which is the TRL intended to be reached at the end of the project? Which are the necessary activities in order to achieve this TRL by the end of the project? Please describe the ongoing and foreseen activities.
The newest system of MicroVent will be implemented on at least one of the demos I RINNO. The project will prove, that the product is fully ready for commercial deployment and therefore TR9.
3. Which are the main foreseen barriers to obtain what is intended to be achieved?
New electronics and software are being developed for MicroVent to achieve wireless communication and operation/monitoring of the system via Cloud solution. There is a risk that the software errors can result in reduced comfort, however, it is possible to update the system software online, and therefore any errors occurring can be corrected at no cost. In relation to the (potential) Danish demo building, it can be a challenge that there are conservatories on one side of the building. Likewise, it may be a challenge if the building is made of concrete walls, i.e., with reinforced concrete on the inner wall. This will mean increased installation costs.
4. From TRL intended to be reached at the end of the project and TRL 9, please provide a description of the R&D activities you think will be necessary to reach each new level of TRL.
Not relevant for MicroVent.
5. Provide a high-level indication on expected costs and years of research and development needed to TRL 9.
Not relevant for MicroVent.
6. Please provide a list and a description of the expected costs categories to TRL 9.
Confidential

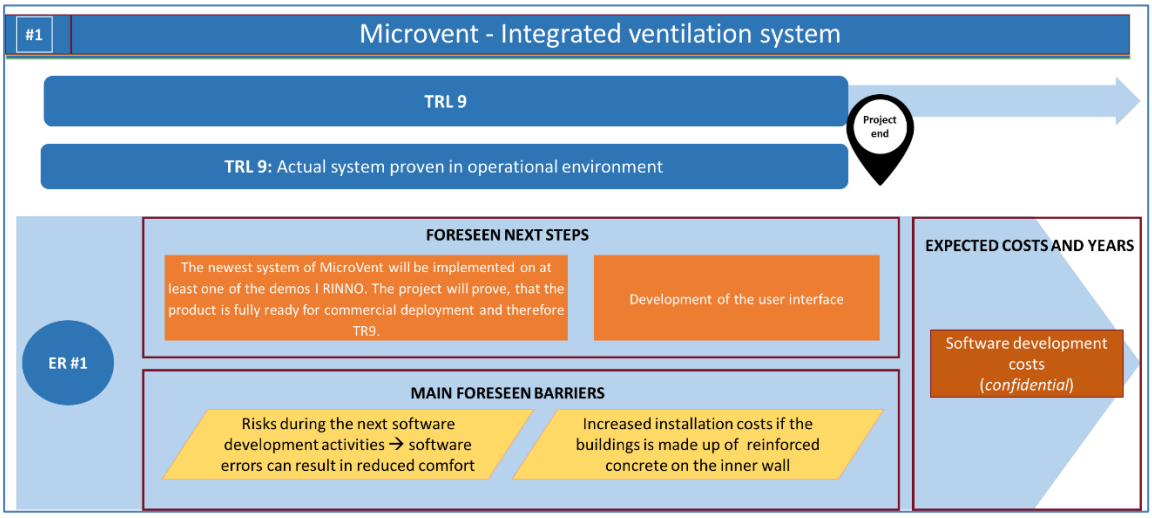


Figure 3-2: MicroVent TRL 9 Roadmap

3.3.2 Kompromentent PV-Roof and Facade solutions (EKOLAB)

The universal envelope for facades, incorporating natural slate and PV (*Kompromentent*) developed by EKOLAB is currently ad TRL 9. During the project, different R&D activities have been performed in order to reach this result.

The following table shows the data needed to conduct a TRL assessment and to design a TRL roadmap. In particular, the questionnaire and the roadmap contain the activities carried out within the project to achieve these results, the main foreseen barriers and challenges to obtain what is intended to be achieved within the project and an indication of expected costs.

Table 3-11: Kompromentent TRL 9 Roadmap questionnaire

QUESTIONNAIRE
1. Which is the actual Technology Readiness Level (TRL) of the technology "KOMPROMENT PV-ROOF AND FACADE SOLUTIONS"? Please provide further information about all the activities that you performed so far during the Project.
The product has upgraded from TRL8 – TRL9 by performing the following activities during RINNO, since June 2020: • Replacement of aluminium battens and hooks with stainless steel • In house production of the PV modules (performing better price / performance on PV)
2. Which is the TRL intended to be reached at the end of the project? Which are the necessary activities in order to achieve this TRL by the end of the project? Please describe the ongoing and foreseen activities.
The product has reached TRL 9 and is in its final form and ready for commercial deployment. It is currently examining the possibilities on the German market, expanding further from the Danish market.
3. Which are the main foreseen barriers to obtain what is intended to be achieved?

• If customers do not prioritize aesthetics or quality materials, but go with the cheapest possible construction cost for a façade with energy production • If country specific legislations do not allow the solution (e.g., fire restrictions or network access) • If the solution and its qualities are not known to the decision makers
4. From TRL intended to be reached at the end of the project and TRL 9, please provide a description of the R&D activities you think will be necessary to reach each new level of TRL.
Not relevant for this technology
5. Provide a high-level indication on expected costs and years of R&D needed to TRL 9.
Confidential
6. Please provide a list and a description of the expected costs categories to TRL 9.
Confidential

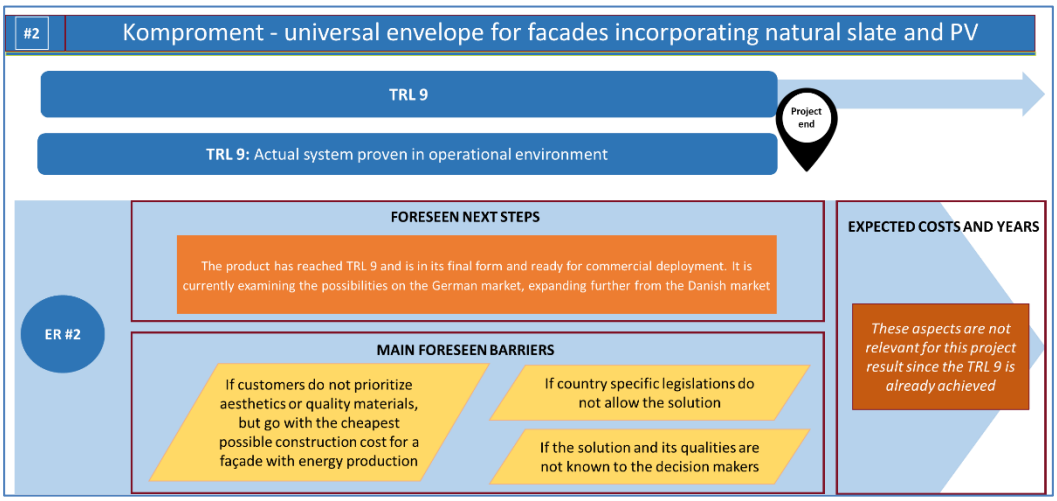


Figure 3-3: Kompro ment TRL 9 Roadmap

3.3.3 Isocell Cellulose Insulation (EKOLAB)

The Isocell Cellulose Insulation, a 90% bio-based material for insulating roofs, walls, or ceilings, developed by EKOLAB is currently ad TRL 9. During the project, different R&D activities have been performed in order to reach this result, here below reported:

- CBI Denmark fusion with Paperwool Denmark → NViro;
- Borate-free option, qualified to use in The Nordic Ecolabel;
- Compress technique achieving lambda 35; 0,035 W/(m*K);
- Insulation of modular walls off-site on factory (prefab walls to be delivered on truck to building site - 2 places in Denmark – 3 places to come);
- Insulation in a lightweight exterior wall construction retrofitted on the old exterior wall (The insulation is inflated between a steel system mounted on the old wall and the wind barrier material).

The product is ready to reach the market and there are no further R&D activities to perform. At this stage, there are also no foreseen barriers or challenges to mention.

3.3.4 Bio-based materials (K-FLEX POLSKA)

The bio-based materials developed by K-FLEX is used to produce different products, such as tubes, sheets, K-BOX and double layer panel. A lot of tests and activities with changing a ration between raw materials was done to receive proper masterbatch which can be used in the next stage of production.

The following table shows the data needed to conduct a TRL assessment and to design a TRL roadmap. In particular, the questionnaire and the roadmap contain the activities carried out within the project to achieve these results, the main foreseen barriers and challenges to obtain what is intended to be achieved within the project and an indication of expected costs.

Table 3-12: Bio-based material TRL 9 Roadmap questionnaire

<table>
<tr><th>QUESTIONNAIRE</th></tr>
<tr><td>1. Which is the actual Technology Readiness Level (TRL) of the technology “BIO-BASED MATERIALS”? Please provide further information about all the activities that you performed so far during the Project.</td></tr>
<tr><td>The development of new products started with the replacement of the standard raw materials for a new, bio-based ones. At the beginning it caused a lot of technological problems. Bio-based EPDM, used to produce tubes, sheets and K-BOX, caused a decrease in viscosity of made rubber mixture. A lot of tests and activities with changing a ration between raw materials was done to receive proper masterbatch which can be used in the next stage of production. Similar situation was with PUR foam for double-layer panels. Substitution of standard polyol by bio-based polyol caused problems with time of polymerization. During production of PUR foam important is to have correct gel time and reaction time in right place in the production line. In this case also was done tests with different combination of raw materials to receive proper foam.
<table>
<tr><td>Bio-based tubes</td><td>TRL 8</td></tr>
<tr><td>Bio-based sheets</td><td>TRL 9</td></tr>
<tr><td>Bio-based K-BOX</td><td>TRL 9</td></tr>
<tr><td>Bio-based double layer panels</td><td>TRL 8</td></tr>
</table>
</td></tr>
<tr><td>2. Which is the TRL intended to be reached at the end of the project? Which are the necessary activities in order to achieve this TRL by the end of the project? Please describe the ongoing and foreseen activities.</td></tr>
</table>

For every product TRL 9 will be received.
During the tests we discover that new bio-based EPDM vulcanizes in different way than standard one. Vulcanization is starting a few seconds earlier what has significant influence during production. To make good foam from final batch two reactions take place simultaneously: vulcanization and foaming. The kinetics of first has a great influence on the course of the second, and vice versa. After tests finally we could receive proper foam product with new formulation. Small difficulty is with big dimensions pipes. Foamed rubber is very good thermal insulation and because of that correct execution of the process is extremely difficult. Heat needs to be delivered as evenly as possible throughout the volume to have no changes in vulcanization and foaming reactions. If temperature is to low or amount of vulcanization system is too small than material inside the pipe is not properly cross-linked. In opposite situation when temperature is too high, or amount of vulcanization system is also to high than outside surface of pipe is cracking. This situation is not very difficult because we deal with such problems almost in every month. In next weeks optimalization of the process will be done.
Production of bio-based double layer panels (PUR + SBR) is not running with normal speed and conditions because during tests we discover that our production line have to be modified. To produce PUR foam from bio-based materials we need to have more control of the process.

3. Which are the main foreseen barriers to obtain what is intended to be achieved ?
The main barriers to obtain products with properties described in proposal are related with the properties of bio-based raw material. In technical data sheets properties are looking very similar to product which are normally used in K-FLEX. The problem is in the details. New raw materials cases changes in properties of products because differences in vulcanization time (EPDM rubber) or polymerization time (PUR foam).
4. From TRL intended to be reached at the end of the project and TRL 9, please provide a description of the R&D activities you think will be necessary to reach each new level of TRL.
Not relevant because TRL 9 is reached for almost all the products.
5. Provide a high-level indication on expected costs and years of R&D needed to TRL 9.
Confidential
6. Please provide a list and a description of the expected costs categories to TRL 9.
Confidential

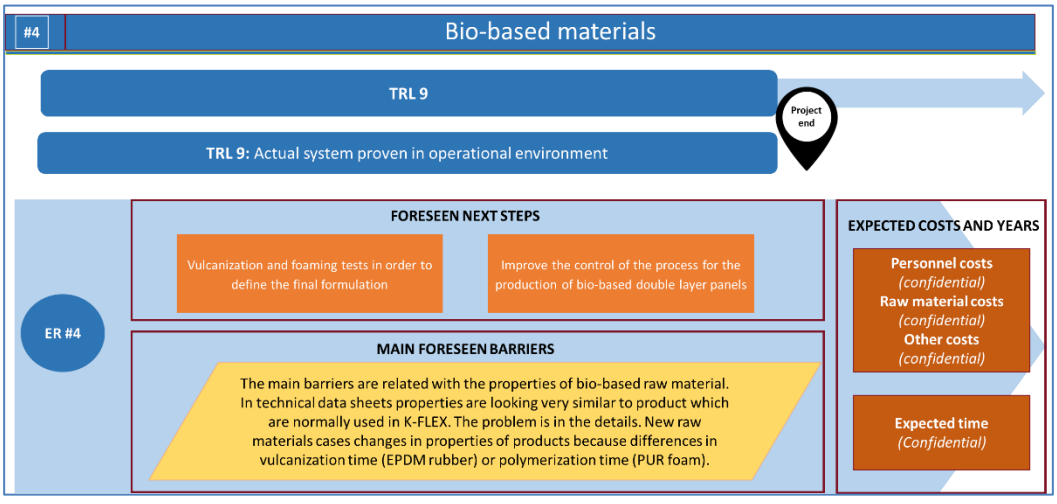


Figure 3-4: Bio-based materials TRL 9 Roadmap

3.3.5 Building Integrated Photovoltaic Glass (GREENSTRUCT)

The Building Integrated Photovoltaic Glass developed by GREENSTRUCT was at TRL 8 at the beginning of the project and it will reach TRL 9 by the end.

The following table shows the data needed to conduct a TRL assessment and to design a TRL roadmap. In particular, the questionnaire and the roadmap contain the activities carried out within the project to achieve these results, the main foreseen barriers and challenges to obtain what is intended to be achieved within the project and an indication of expected costs.

Table 3-13: Building Integrated Photovoltaic Glass TRL 9 Roadmap questionnaire

QUESTIONNAIRE
1. Which is the actual Technology Readiness Level (TRL) of the technology "BUILDING INTEGRATED PHOTOVOLTAIC GLASS"? Please provide further information about all the activities that you performed so far during the Project. (You can find further details on TRL in the Error! Reference source not found.).
Building Integrated photovoltaic glass was at TRL 8 when the program started. It was being used in many different building applications such as façade, canopy, balustrades etc. Through the course of the RINNO project, we manufactured a prefabricated aluminium module that incorporates BIPV glasses along with insulation panels on the back of the module. By the end of the RINNO project this technology will be TRL9.
2. Which is the TRL intended to be reached at the end of the project? Which are the necessary activities in order to achieve this TRL by the end of the project? Please describe the ongoing and foreseen activities.
The TRL intended to be reached at the end of the project is 9. First and most important activity is the trial installation of the prefabricated module so we can troubleshoot and debug the process. Also very important activity for the TRL9 phase is the implementation of the system in actual building and receive data concerning its use so we can promote it in various channels and help all relevant parties that are interested in this technology to have these valuable details.
3. Which are the main foreseen barriers to obtain what is intended to be achieved?
Lack of interest from parties involved in the building industry. Raw materials price increase and following proper justification of why people should use these technologies due to high price.
4. From TRL intended to be reached at the end of the project and TRL 9, please provide a description of the R&D activities you think will be necessary to reach each new level of TRL.
The technology was TRL8 at the beginning of the RINNO project and doesn't need any additional R&D in order to reach TRL9
5. Provide a high-level indication on expected costs and years of R&D needed to TRL 9.
Not relevant since the technology is very close to TRL 9
6. Please provide a list and a description of the expected costs categories to TRL 9.
Not relevant since the technology is very close to TRL 9

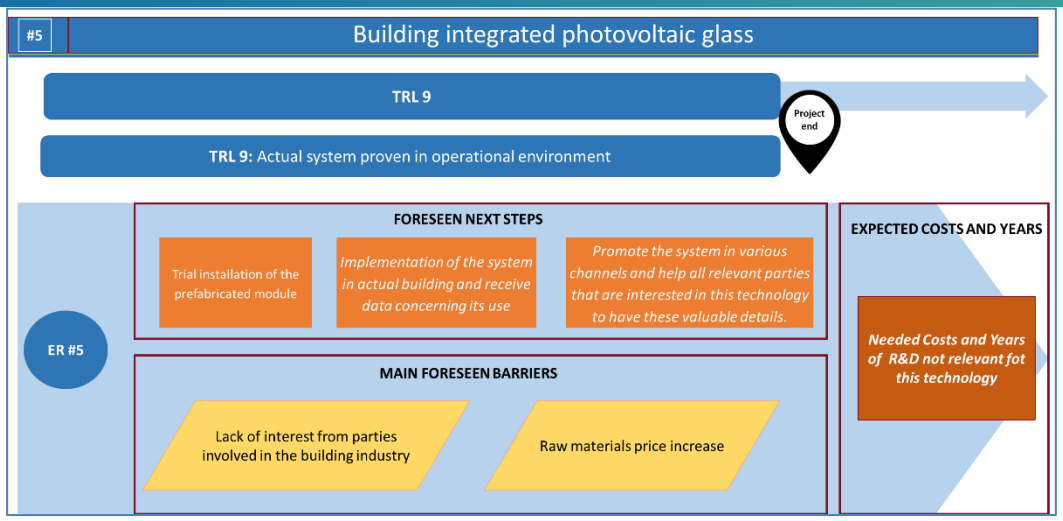


Figure 3-5: Building Integrated Photovoltaic Glass TRL 9 Roadmap

3.3.6 Thermochromic Glass (GREENSTRUCT)

The Thermochromic Glass developed by GREENSTRUCT was at TRL 8 at the beginning of the project and it will reach TRL 9 by the end.

The following table shows the data needed to conduct a TRL assessment and to design a TRL roadmap. In particular, the questionnaire and the roadmap contain the activities carried out within the project to achieve these results, the main foreseen barriers and challenges to obtain what is intended to be achieved within the project and an indication of expected costs.

Table 3-14: Thermochromic Glass TRL 9 Roadmap questionnaire

QUESTIONNAIRE
1. Which is the actual Technology Readiness Level (TRL) of the technology "THERMOCHROMIC GLASS"? Please provide further information about all the activities that you performed so far during the Project. (You can find further details on TRL in the Error! Reference source not found.).
The thermochromic glasses were at TRL8 when the project started. It was being used to large scale commercial buildings mainly due to the high price of the material as well as the lack of knowledge from the architects and constructors. During the RINNO project we manufactured various typologies of thermochromic glass in order to apply the best possible solution in pilot buildings.
2. Which is the TRL intended to be reached at the end of the project? Which are the necessary activities in order to achieve this TRL by the end of the project? Please describe the ongoing and foreseen activities.
The TRL intended to be reached at the end of the project is 9. In order for the thermochromic glass to reach this TRL, we need to install them in an actual pilot building and start showing all the interested parties the benefits of using such technologies.
3. Which are the main foreseen barriers to obtain what is intended to be achieved ?
Lack of interest from parties involved in the building industry. Raw materials price increase and following proper justification of why people should use these technologies due to high price.

4. From TRL intended to be reached at the end of the project and TRL 9, please provide a description of the R&D activities you think will be necessary to reach each new level of TRL.
The technology was TRL8 at the beginning of the RINNO project and doesn't need any additional R&D in order to reach TRL9
5. Provide a high-level indication on expected costs and years of R&D needed to TRL 9.
Not relevant since the technology is very close to TRL 9
6. Please provide a list and a description of the expected costs categories to TRL 9.
Not relevant since the technology is very close to TRL 9

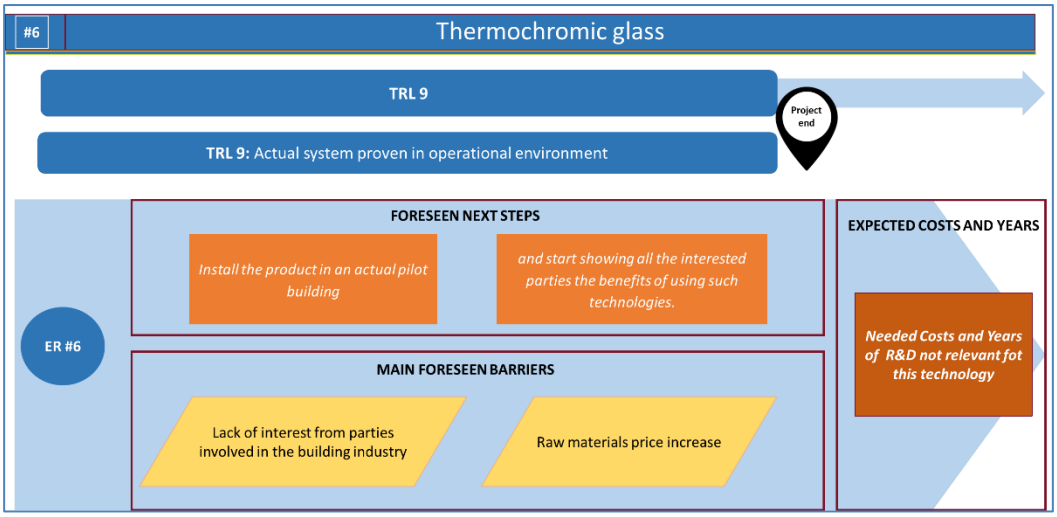


Figure 3-6: Thermochromic Glass TRL 9 Roadmap

3.3.7 De-centralized domestic hot water preparation (PINK)

The standard version of the product is already at TRL 8-9. Detailed technical drawings and functional diagrams were created for all aspects of the system for domestic hot water preparation, whereby the following components have been considered:

- storage tank (wall-integrated and wall-mounted);
- charging systems (thermal and electrical charging);
- hydraulic units (various designs);
- control systems (thermal and electrical charging).

The following questionnaire shows the data needed to conduct a TRL assessment and to design a TRL roadmap for each different component. In particular, it contains the activities carried out within the project to achieve the actual TRL, the main foreseen barriers and challenges to obtain what is intended to be achieved within the project and an indication of expected costs.

Table 3-15: De-centralized domestic hot water preparation TRL 9 Roadmap questionnaire

QUESTIONNAIRE
1. Which is the actual Technology Readiness Level (TRL) of the technology "DE-CENTRALIZED DOMESTIC HOT WATER PREPARATION"? Please provide further information about all the activities that you performed so far during the Project. (You can find further details on TRL in the Error! Reference source n ot found.).
For the standard version of the product, the TRL 8-9 has already been achieved. Therefore detailed technical drawings and functional diagrams were created for all aspects of the system for domestic hot water preparation, whereby the following components have been considered: • storage tank (wall-integrated and wall-mounted) • charging systems (thermal and electrical charging) • hydraulic units (various designs) • control systems (thermal and electrical charging) However, individual components of the overall solution are still under development, which is why their TRL is still 4-5 here.
2. Which is the TRL intended to be reached at the end of the project? Which are the necessary activities in order to achieve this TRL by the end of the project? Please describe the ongoing and foreseen activities.
For the innovative products for decentralized water heating, a TRL 9 is targeted within the project, so the overall system should be developed to such an extent that they are ready for commercial use. (for individual components of the overall system this is already applied, see above). One topic in achieving a higher TRL is the consideration of regulations and standards such as EN 806-3, EN 1488 and DELEGATED REGULATION (EU) No 812/2013, which are relevant when using decentralized hot water storage tanks. Compliance with these standards and regulations have to, among other things, be verified by recording appropriate variables during operation of the domestic hot water storage tank. For this purpose, an in-house test bench was set up at the Pink company, with which these measurements will be carried out. In addition, the real implementation of the products within the demo buildings of RINNO will also be important for further development, as these activities will provide important insights for the installation and operation of the system. Also improvements that can be achieved there, both in terms of energy use and the optimized implementation of deep renovation projects, can drive the product development forward. For the bio-based isolation of the wall-integrated storage tank, the first attempts of the development were started. Within the project, the implementation, the measurements, and the installation in the demo buildings should take place.
3. Which are the main foreseen barriers to obtain what is intended to be achieved?
The extremely unstable situation regarding the trend of market prices in nearly all sectors is currently the greatest barrier of the product development. Because in addition to the significantly increased actual product costs of the system for decentralized domestic hot water preparation (steel for storage tanks, supplier components such as fittings, etc.), the general increase of the cost of building materials in construction projects, both in new buildings and in renovations, has a negative effect on the frequency of implementation. Due to the increased costs, such projects sometimes are no longer going to be realized or at least they are temporally postponed, which in turn leads to strong fluctuations in the demand for the actual products. So a stable planning for product developments and potential prospective sales is currently hardly possible. Also the strongly increased delivery times of individual components, such as those of the controls, are currently a very big challenge in this area. In particular, the insufficient availability of raw materials had negative effects on the development of the bio-based insulation of the wall integrated storage tanks, which has to be realized together with the project partner K-Flex.

4. From TRL intended to be reached at the end of the project and TRL 9, please provide a description of the R&D activities you think will be necessary to reach each new level of TRL.
The product development of the system for decentralized domestic hot water preparation is not a single product, but an overall system, which in turn consists of individual components. The following list shows the components of the system and the associated TRL (at the beginning and intended for the end of the project): • Wall integrated storage tank 7 -> 9 • Wall mounted storage tank 8 -> 9 • Electrical charging system 6 -> 9 • Electrical control system 7 -> 9 • Hydraulic charging system 7 -> 9 • Hydraulic control system 7 -> 9 • Prefabricated hydraulic module 8 -> 9 • Biobased Insulation 5 -> 8 Therefore, the increase of the TRL of the overall system is based on a large number of R&D activities, which mostly affects the individual components but also the interaction of each other, an orderly description is not possible here. In general, however, the activities have already been described in point 2.
5. Provide a high-level indication on expected costs and years of R&D needed to TRL 9.
Confidential
6. Please provide a list and a description of the expected costs categories to TRL 9.
Confidential

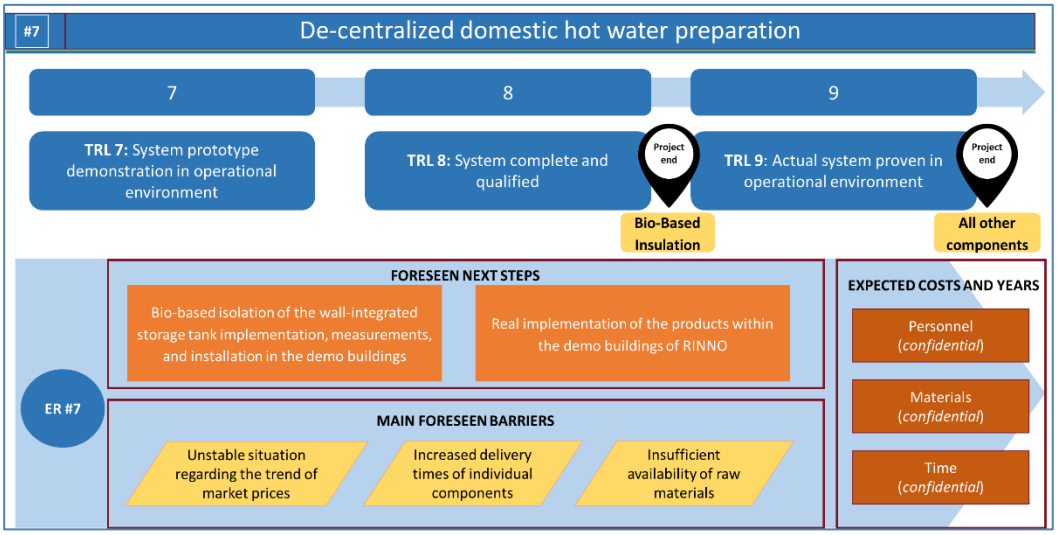


Figure 3-7: De-centralized domestic hot water preparation TRL 9 Roadmap

4 Conclusions

The present report is a public deliverable (Deliverable D1.2 “RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (Final)”) 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 scopes of this report are the following:

1. update the preliminary list of key requirements, needs, barriers and challenges, from the point of view of different stakeholders involved in the renovation value chain, defined in D 1.1;
2. define a TRL 9 roadmap for each exploitable results, identifying foreseen R&D activities in order to reach what was intended to be reached at the end of the project, main barriers and challenges to obtain each new level of TRL and a forecast of costs and years needed.

The review of the requirements has been based starting from the analysis performed in the first version of the deliverable (D1.1). The categories identified during the above-mentioned analysis has been maintained as follow:

- Technical aspects;
- Economical aspects;
- Environmental;
- Materials;
- Social aspects.

Based on what has been done for the deliverable 1.7 “*Report on RINNO KPIs (Final Version)*”, a KPI has been associated with each key requirement (where possible) so as to associate them an evaluation parameter (chapter 2.2).

An indication of the occupants’ needs and requirements has been reported based on what emerged from Task 1.3 "Pilot Sites Surveys & Definition of Use Case Renovation Scenarios," whose results are presented in deliverable D 1.4 "RINNO Pilot Analysis and Deployment Plan" (chapter 2.3). In this section, comparison between the need of the residents of the different demo cases has been reported, emphasizing the objectives of major importance for each defined category “*Energy-related*”, “*Economical*”, “*Social*” and “*Environmental*”. These aspects should be taken into consideration when planning deep renovation process.

In addition, a Technological Roadmap has been defined for each exploitable result. A specific questionnaire has been shared within partners to collect information regarding the development of the technology they technology they were responsible for, such as:

- Actual TRL of the technology;
- Activities performed so far to reach the actual TRL;
- Main foreseen R&D activities to reach what was intended to be reached;
- Main foreseen barriers and challenges;
- Expected costs and years needed to reach TRL 9

Almost all the RINNO technologies are at a very high TRL (8/9) but there are still several R&D activities to perform in order to reach the right technology maturity.

ANNEXES

ANNEX 1. CONFIDENTIAL INFORMATION

MicroVent – Sustainable Ventilation (In Ventilate – EKOLAB)

The integrated ventilation system with low power consumption (*MicroVent*) developed by EKOLAB is currently ad TRL 9. During the project, different R&D activities have been performed in order to reach this result.

The following table shows the data needed to conduct a TRL assessment and to design a TRL roadmap. In particular, the questionnaire and the roadmap contain the activities carried out within the project to achieve these results, the main foreseen barriers and challenges to obtain what is intended to be achieved within the project and an indication of expected costs.

Table A-01: MicroVent TRL 9 Roadmap questionnaire

QUESTIONNAIRE
1. Which is the actual Technology Readiness Level (TRL) of the technology "MICROVENT"? Please provide further information about all the activities that you performed so far during the Project.
The product has upgraded from TRL8 – TRL9 by performing the following activities during RINNO, since June 2020: • New electronics with wireless communication • Software update with optimized wind compensation • Optimized management for replacement air for the cooker hood • Sound-absorbing solutions for external noise and fan noise • New interior and exterior covers in a more elegant design and easier for installation and service. • New solutions (MicroVent box, MicroVent wall and MicroVent Window)
2. Which is the TRL intended to be reached at the end of the project? Which are the necessary activities in order to achieve this TRL by the end of the project? Please describe the ongoing and foreseen activities.
The newest system of MicroVent will be implemented on at least one of the demos I RINNO. The project will prove, that the product is fully ready for commercial deployment and therefore TR9.
3. Which are the main foreseen barriers to obtain what is intended to be achieved?
New electronics and software are being developed for MicroVent to achieve wireless communication and operation/monitoring of the system via Cloud solution. There is a risk that the software errors can result in reduced comfort, however, it is possible to update the system software online, and therefore any errors occurring can be corrected at no cost. In relation to the (potential) Danish demo building, it can be a challenge that there are conservatories on one side of the building. Likewise, it may be a challenge if the building is made of concrete walls, i.e., with reinforced concrete on the inner wall. This will mean increased installation costs.
4. From TRL intended to be reached at the end of the project and TRL 9, please provide a description of the R&D activities you think will be necessary to reach each new level of TRL.

Not relevant for MicroVent.
5. Provide a high-level indication on expected costs and years of research and development needed to TRL 9.
Not relevant for MicroVent.
6. Please provide a list and a description of the expected costs categories to TRL 9.
Much of the new electronics have already been developed. The user interface is currently under development Expected costs to reach the finish line is around 33.500 Euro

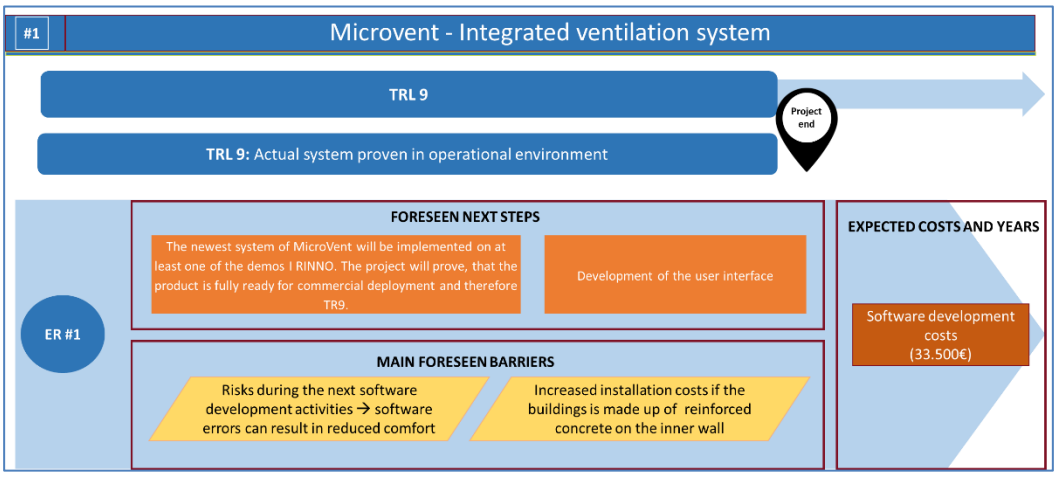


Figure A-1: MicroVent TRL 9 Roadmap

Bio-based materials (K-FLEX POLSKA)

The bio-based materials developed by K-FLEX is used to produce different products, such as tubes, sheets, K-BOX and double layer panel. A lot of tests and activities with changing a ration between raw materials was done to receive proper masterbatch which can be used in the next stage of production.

The following table shows the data needed to conduct a TRL assessment and to design a TRL roadmap. In particular, the questionnaire and the roadmap contain the activities carried out within the project to achieve these results, the main foreseen barriers and challenges to obtain what is intended to be achieved within the project and an indication of expected costs.

Table A-1: Bio-based material TRL 9 Roadmap questionnaire

QUESTIONNAIRE
1. Which is the actual Technology Readiness Level (TRL) of the technology "BIO-BASED MATERIALS"? Please provide further information about all the activities that you performed so far during the Project.
The development of new products started with the replacement of the standard raw materials for a new, bio-based ones. At the beginning it caused a lot of technological problems. Bio-based EPDM, used to produce tubes, sheets and K-BOX, caused a decrease in viscosity of made rubber mixture. A lot of tests and activities with changing a ration between raw materials was done to receive proper masterbatch which can be used in the next stage of production. Similar situation was with PUR foam for double-layer panels. Substitution of standard polyol by bio-based polyol caused problems with time of polymerization. During production of PUR foam important is to have correct gel time and reaction time in right place in the production line. In this case also was done a tests with different combination of raw materials to receive proper foam.

Bio-based tubes	TRL 8
Bio-based sheets	TRL 9
Bio-based K-BOX	TRL 9
Bio-based double layer panels	TRL 8

2. Which is the TRL intended to be reached at the end of the project? Which are the necessary activities in order to achieve this TRL by the end of the project? Please describe the ongoing and foreseen activities.
For every product TRL 9 will be received. During the tests we discover that new bio-based EPDM vulcanizes in different way than standard one. Vulcanization is starting a few seconds earlier what has significant influence during production. To make good foam from final batch two reactions take place simultaneously: vulcanization and foaming. The kinetics of first has a great influence on the course of the second, and vice versa. After tests finally we could receive proper foam product with new formulation. Small difficulty is with big dimensions pipes. Foamed rubber is very good thermal insulation and because of that correct execution of the process is extremely difficult. Heat needs to be delivered as evenly as possible throughout the volume to have no changes in vulcanization and foaming reactions. If temperature is to low or amount of vulcanization system is too small than material inside the pipe is not properly cross-linked. In opposite situation when temperature is too high, or amount of vulcanization system is also to high than outside surface of pipe is cracking. This situation is not very difficult because we deal with such problems almost in every month. In next weeks optimalization of the process will be done. Production of bio-based double layer panels (PUR + SBR) is not running with normal speed and conditions because during tests we discover that our production line have to be modified. To produce PUR foam from bio-based materials we need to have more control of the process.
3. Which are the main foreseen barriers to obtain what is intended to be achieved ?
The main barriers to obtain products with properties described in proposal are related with the properties of bio-based raw material. In technical data sheets properties are looking very similar to product which are normally used in K-FLEX. The problem is in the details. New raw materials cases changes in properties of products because differences in vulcanization time (EPDM rubber) or polymerization time (PUR foam).
4. From TRL intended to be reached at the end of the project and TRL 9, please provide a description of the R&D activities you think will be necessary to reach each new level of TRL.
Not relevant because TRL 9 is reached for almost all the products.
5. Provide a high-level indication on expected costs and years of R&D needed to TRL 9.

Expected costs: 200 000 euro **Expected months:** 18 months
6. Please provide a list and a description of the expected costs categories to TRL 9.
Personnel costs: 115 000 euro **Cost of raw materials:** 45 000 euro **Other costs:** 40 000 euro

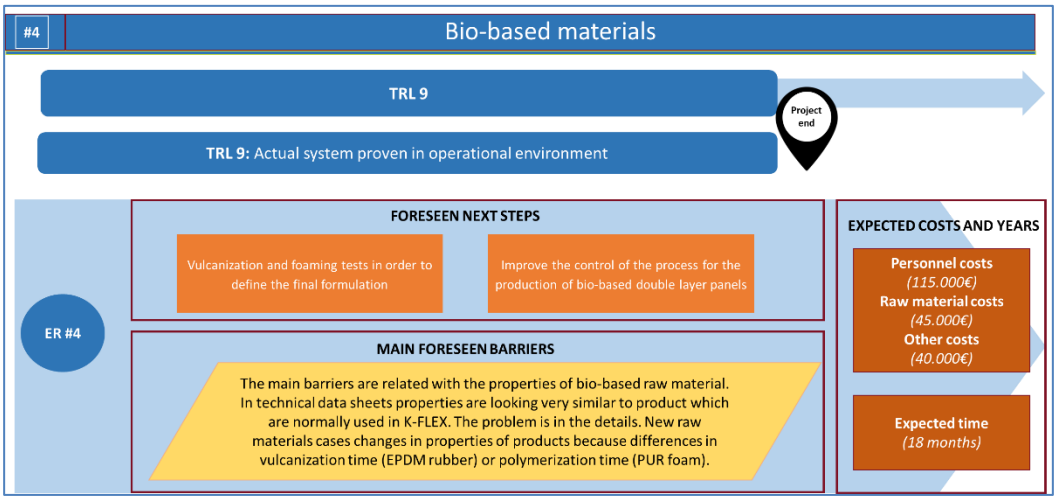


Figure A-2: Bio-based materials TRL 9 Roadmap

De-centralized domestic hot water preparation (PINK)

The standard version of the product is already at TRL 8-9. Detailed technical drawings and functional diagrams were created for all aspects of the system for domestic hot water preparation, whereby the following components have been considered:

- storage tank (wall-integrated and wall-mounted);
- charging systems (thermal and electrical charging);
- hydraulic units (various designs);
- control systems (thermal and electrical charging).

The following questionnaire shows the data needed to conduct a TRL assessment and to design a TRL roadmap for each different component. In particular, it contains the activities carried out within the project to achieve the actual TRL, the main foreseen barriers and challenges to obtain what is intended to be achieved within the project and an indication of expected costs.

Table A-2: De-centralized domestic hot water preparation TRL 9 Roadmap questionnaire

QUESTIONNAIRE
1. Which is the actual Technology Readiness Level (TRL) of the technology "DE-CENTRALIZED DOMESTIC HOT WATER PREPARATION"? Please provide further information about all the activities that you performed so far during the Project. (You can find further details on TRL in the Error! Reference source n ot found.).
For the standard version of the product, the TRL 8-9 has already been achieved. Therefore detailed technical drawings and functional diagrams were created for all aspects of the system for domestic hot water preparation, whereby the following components have been considered: • storage tank (wall-integrated and wall-mounted) • charging systems (thermal and electrical charging) • hydraulic units (various designs) • control systems (thermal and electrical charging) However, individual components of the overall solution are still under development, which is why their TRL is still 4-5 here.
2. Which is the TRL intended to be reached at the end of the project? Which are the necessary activities in order to achieve this TRL by the end of the project? Please describe the ongoing and foreseen activities.
For the innovative products for decentralized water heating, a TRL 9 is targeted within the project, so the overall system should be developed to such an extent that they are ready for commercial use. (for individual components of the overall system this is already applied, see above). One topic in achieving a higher TRL is the consideration of regulations and standards such as EN 806-3, EN 1488 and DELEGATED REGULATION (EU) No 812/2013, which are relevant when using decentralized hot water storage tanks. Compliance with these standards and regulations have to, among other things, be verified by recording appropriate variables during operation of the domestic hot water storage tank. For this purpose, an in-house test bench was set up at the Pink company, with which these measurements will be carried out. In addition, the real implementation of the products within the demo buildings of RINNO will also be important for further development, as these activities will provide important insights for the installation and operation of the system. Also improvements that can be achieved there, both in terms of energy use and the optimized implementation of deep renovation projects, can drive the product development forward. For the bio-based isolation of the wall-integrated storage tank, the first attempts of the development were started. Within the project, the implementation, the measurements, and the installation in the demo buildings should take place.
3. Which are the main foreseen barriers to obtain what is intended to be achieved?
The extremely unstable situation regarding the trend of market prices in nearly all sectors is currently the greatest barrier of the product development. Because in addition to the significantly increased actual product costs of the system for decentralized domestic hot water preparation (steel for storage tanks, supplier components such as fittings, etc.), the general increase of the cost of building materials in construction projects, both in new buildings and in renovations, has a negative effect on the frequency of implementation. Due to the increased costs, such projects sometimes are no longer going to be realized or at least they are temporally postponed, which in turn leads to strong fluctuations in the demand for the actual products. So a stable planning for product developments and potential prospective sales is currently hardly possible. Also the strongly increased delivery times of individual components, such as those of the controls, are currently a very big challenge in this area. In particular, the insufficient availability of raw materials had negative effects on the development of the bio-based insulation of the wall integrated storage tanks, which has to be realized together with the project partner K-Flex.

4. From TRL intended to be reached at the end of the project and TRL 9, please provide a description of the R&D activities you think will be necessary to reach each new level of TRL.

The product development of the system for decentralized domestic hot water preparation is not a single product, but an overall system, which in turn consists of individual components. The following list shows the components of the system and the associated TRL (at the beginning and intended for the end of the project):

- Wall integrated storage tank 7 -> 9
- Wall mounted storage tank 8 -> 9
- Electrical charging system 6 -> 9
- Electrical control system 7 -> 9
- Hydraulic charging system 7 -> 9
- Hydraulic control system 7 -> 9
- Prefabricated hydraulic module 8 -> 9
- Biobased Insulation 5 -> 8

Therefore, the increase of the TRL of the overall system is based on a large number of R&D activities, which mostly affects the individual components but also the interaction of each other, an orderly description is not possible here. In general, however, the activities have already been described in point 2.

5. Provide a high-level indication on expected costs and years of R&D needed to TRL 9.

Due to the situation described above, it is also very difficult to estimate the costs of raising the TRL from 7 to 9. Because in addition to the complex system structure, the small company size also makes it difficult for the PINK company to carry out a detailed cost analysis. On the one hand, these small and flexible structures allow very rapid and targeted development of the products, but the exact assignment to the cost centers is often not possible. However, a very rough estimate of the cost to TRL 9 can be given with a value of:

Expected costs:

- development costs € 300.000 (rough estimation)

With regard to the timeline, it has already been described that, based on TRL 7 at the beginning of the project, the development within the project period of 4 years for all relevant components of the system should be completed so far, in principle there is no need for a reassessment here.

Expected years:

- 2 years 7 -> 8 (reached at M24)
- 2 years 8 -> 9 (reached at M48)

6. Please provide a list and a description of the expected costs categories to TRL 9.

So far, the largest cost factor in the product development results from the activities of the employees involved in the topic, whereby not only the actual research staff but also the employees in production, project development and project management make a contribution. In simplified terms, the personnel costs of two employees over the period of 4 years can be used as a very rough estimation. The remaining part of the total costs is accounted for by the materials:

- Personnel costs € 250.000 (rough estimation)
- Material costs € 50.000 (rough estimation)

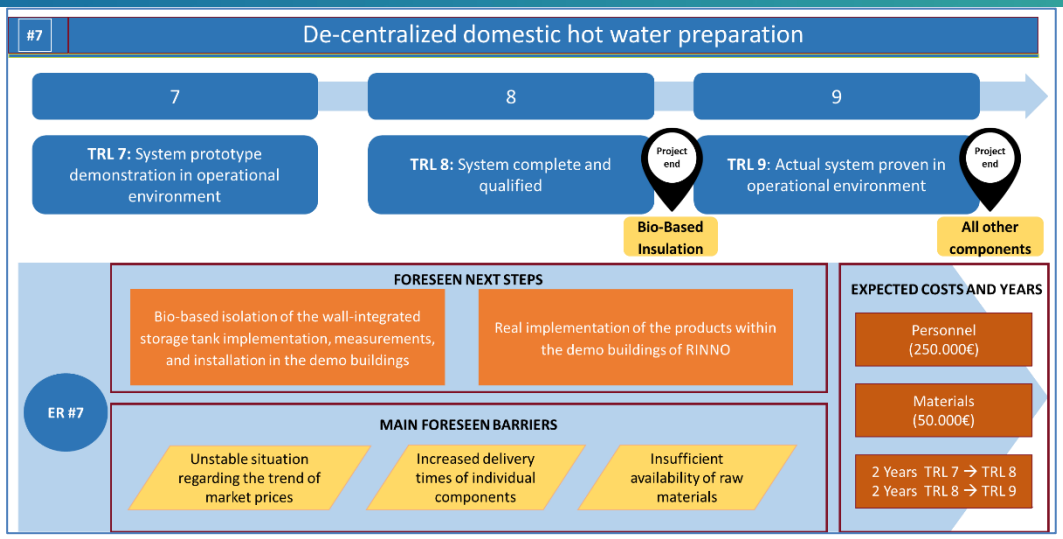


Figure A-3: De-centralized domestic hot water preparation TRL 9 Roadmap

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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