RINNO

RINNO PROJECT

Report

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

Deliverable 5.7: Standardization of RINNO's Building Renovation Passports and Logbook

Work Package 5: RINNO Operational Platform with Augmented Intelligence

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Executive Summary

The present report is a public deliverable (Deliverable 5.7 – Report about Standardization of RINNO's Building Renovation Passports and Logbook) of the RINNO H2020 funded European project, "An augmented intelligence-enabled stimulating framework for deep energy renovation delivering occupant-centred innovations".

The RINNO project aims to deliver a framework solution that will help drastically accelerating the rate of deep renovation in EU building stock reaching an ambitious annual renovation rate of 3.5%. 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 (planning-design, retrofitting, monitoring).

To reach these objectives, task 5.5 will develop and contribute to the standardization of Building Renovation Passports and Logbook, while RINNOs outputs will be matched with the key components of BRPs.

The following deliverable is organized in 6 chapters. The **first chapter** introduces the work carried out by T5.5, its objectives, and main activities. The **second chapter** consists of a literature review examining the existing publications on the main concepts of Building Renovation Passports (BRPs) and Logbook. The **third chapter** provides an overview of the methodology and development of the renovation roadmap as part of the RINNO platform. The **fourth chapter** is dedicated to the RINNO logbook creation. **Chapter five** provides an overview of the related experiences from the full-scale demonstration projects and outlines generic guidelines and technical advisory for stakeholders. **Chapter six** concludes on the activities and the possible standardization of BRPs.

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Abbreviations List

API	Application Programming Interface
BMS	Building Monitoring System
BP	Building Passport
BRP	Building Renovation Passport
DBL	Digital Building Logbook
EE	Energy Efficiency
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
HVAC	Heating Ventilation and Air Conditioning
IoT	Internet of Things
KPI	Key Performance Indicator
RES	Renewable Energy Sources
REST API	Representational State Transfer API
RLRM	RINNO Lifecycle Renovation Manager
RM	RINNO Marketplace
RPDA	RINNO Planning & Design Assistant
RR	Renovation Roadmap
RRM	RINNO Retrofitting Manager
RRR	RINNO Renovation Repository
RSA	RINNO Simulation and Assessment
RWM	Renovation Workflow Manager
WP	Work Package

1. Introduction

This report describes the results of the work undertaken in the context of task T5.5 – "Building Renovation Passports & Logbook". Final purpose of the task is to identify, consolidate and present in a meaningful way the outcomes, and experiences of RINNO that can potentially strengthen the development and standardization of Building Renovation Passports (BRPs). RINNO's outputs will be matched with the key components of BRPs.

The main objective of a BRP is to propose a step-by-step roadmap for renovation based on an energy audit, that identifies the building condition and the needs of the users. In the context of RINNO on-site data gathering and auditing during the design phase is supported by RINNO's building-as-is data capturing (T3.1). Data processing and continuous monitoring takes place in T5.1 and T5.2 while RINNO's integrated building renovation support system (RPDA) developed in WP3 supports the design of deep renovation scenarios as well as staged renovation. In this task the Renovation Roadmap (RR) is developed considering input from the forementioned tools to provides a tailored, step-by-step renovation solution. The logbook contains all the data from the building including BIM-model and sensor-outputs and uses data capturing technologies and third-party connections developed in (T1.3, T1.4 and T5.1 - T5.3).

The four RINNO pilot sites each represents a unique building with distinct characteristics and challenges. Results and experiences from these full-scale deployments conducted in WP6 are presented and lessons from the pre-renovation, during-renovation and post-renovation phases regarding IoT sensor setups and challenges related to the renovation scenarios are discussed and summarized to guide future developments and decision making regarding BRPs. Specific guidelines are made for decision making bodies, building professionals and end-users to facilitate the wider implementation of BRPs.

1.1. Structure of the deliverable

In chapter 2 a literature review is presented on the two parts of a BRP - the renovation roadmap and the digital logbook.

In chapter 3 the technical development of the RINNO Suite to present a renovation roadmap is described.

Chapter 4 describes the technical development of the RINNO Suite to include the logbook with descriptions of sensor setup, building information and connection to third parties.

In chapter 5 the experiences from the full-scale demonstration projects are communicated and presented as guidelines for future use.

In chapter 6 the conclusion of this report is presented.

1.2. Connection with other tasks and work packages

The Building Renovation Passport and specifically the Renovation Roadmap (RR) with scenarios for staged renovation are based on the tools developed in WP3. The tools have been customized to deliver the necessary inputs required for the BRP methods developed in task 5.5, resulting in a RINNO suite that communicates a RR and logbook.

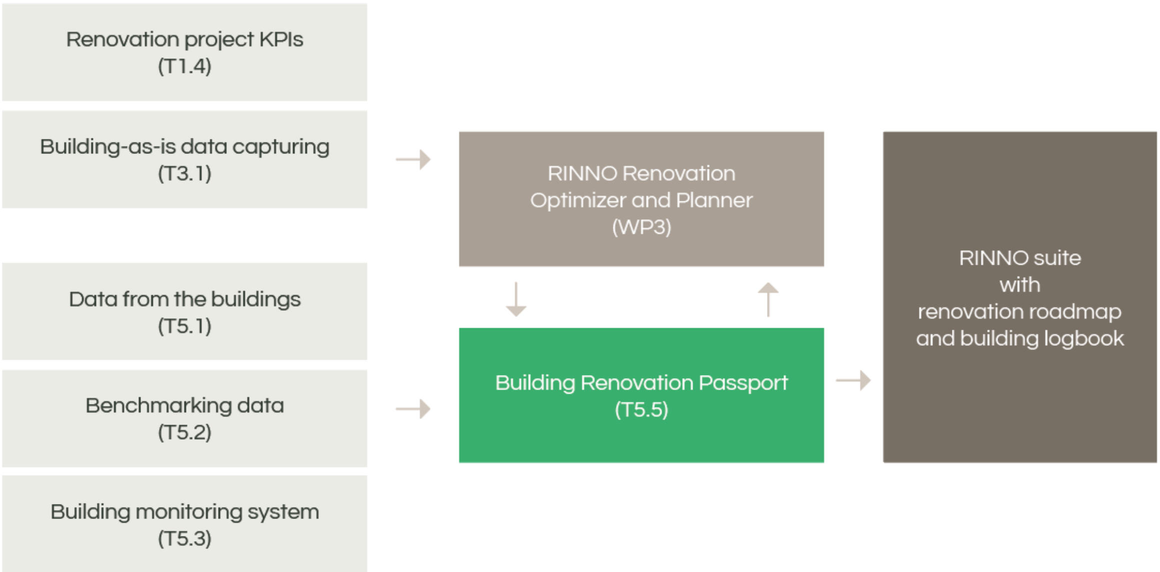

Figure 1. T5.5 connection with other tasks and work packages

2. Literature review

The literature review examines the two concepts constituting the Building Renovation Passport (BRP) namely the renovation roadmap (RR) and the logbook. In Europe the introduction of Building Passports has been discussed for decades, the objective being to provide information to a potential purchaser, investor, tenant or user. But the term has been used with differing meanings to describe varying levels of building information.

The main barriers to the implementation of Building Renovation Passport (BRP), according to (Sesana & Salvalai, 2018) include the lack of standardized definitions, varying meanings of the term "Building Passport", the complexity of compiling an inventory of building materials for existing buildings and difficulties in relation to contamination from harmful substances.

To overcome these barriers, it is essential to establish standardized definitions and structures for BRPs, as well as to develop flexible and open approaches specifically tailored for existing buildings. Furthermore, the use of dedicated software and adaptation of existing energy audit software can aid in the collection of all relevant building information for the creation of BRPs. Ongoing research initiatives, such as the iBRoad project, aim to develop customized renovation plans and building logbooks to address the challenges associated with BRP implementation. These efforts can contribute to overcoming the barriers and promoting the adoption of BRPs across the EU (Sesana & Salvalai, 2018).

In the article on challenges and future roles of European building passports (Buchholz & Lützkendorf, 2023) concluded that at least five different challenges should be addressed in the future research and development.

- *A standardized definition as well as transparency about the incorporated functions*
- *Main functions, including functions that serve the involved actors*
- *Scope of BPs covering an appropriate level of details*
- *BPs and the relation to other tools (BIM, digital twin) that serve as an input, but differ in scope and level of detail*
- *Information and communication technologies ensure technical interoperability and user friendliness.*

The following chapters investigates the literature describing the two concepts first the renovation roadmap and then the logbook.

2.1. Renovation Roadmap

A roadmap is defined in the Cambridge Dictionary as a plan for how to achieve something. A renovation is the process of restoring or replacing existing parts of the building to improve its looks and performance to their original state or better (Ástmarsson, Jensen, & Maslesa, 2013). The aim in the context of European building policy and the RINNO project is to drastically increase the rate of deep renovation. There is no common definition for "deep renovation" or "staged renovation" according to Fabbri et al. (2016), but there are common features among the initiatives. A main argument for deep renovations is that they are a necessity to achieve radical improvements in energy efficiency. (Jensen, Maslesa, Berg, & Thuesen, 2018). Another common feature is to ensure consistency between short- and long-term measures to avoid lock-in effects where one improvement blocks the feasibility of another part of a renovation. The focus in this section is on the literature describing renovation roadmaps and the practical experience with the implementation of RRs.

A renovation roadmap is a step-by-step plan for a specific building that outlines a long-term (up to 15 or 20 years) renovation plan resulting from an on-site energy audit fulfilling specific quality criteria and indicators established during the design phase and in dialogue with building owners. The roadmap suggests the installation of selected measures in a certain order (sequencing) to avoid lock-in effects and to achieve deep staged renovation. The aim is to guide the proprietors to a better performing building over time by taking the most important measures first, in an economically viable way, while taking care of investment/output rates, property value, and comfort improvement. (Sesana & Salvalai, 2018).

The RR is meant as a long-term plan for building improvement, not only as a technical intervention, and should be a guide for the building owner facilitating a more sustainable building renovation. By providing building owners with performance measurements on a number of relevant indicators (e.g. energy consumption, CO2 emissions, thermal and acoustic comfort, indoor air quality and daylight) and links between the different measures the RR supports removing obstacles for deep renovations e.g. providing knowledge about the current and future performance of the building, making technical solutions more easily available, avoiding lock-in effects by highlighting specific elements that should be considered and suggesting the most feasible steps in a staged renovation. The roadmap gives the individual building owners the opportunity to have an overview of the full range of renovation options and easily identify each renovation step from beginning to the end (Fabbri, Groote, & Rapf, 2016).

According to Fabbri et. al (2016) the term building renovation roadmap and passport are used to describe the same concept across the three case studies in the report, and the authors choose the expression “Building Renovation Passport” in the study. It is defined as a document outlining a long-term step-by-step renovation roadmap (or staged renovation) based on an on-site energy audit. The renovation roadmap should have a horizon of up to 15-20 years and informs on the expected benefits in terms of reduced heating bills, comfort improvement and CO2 reduction. It can be combined with building-related information (the logbook).

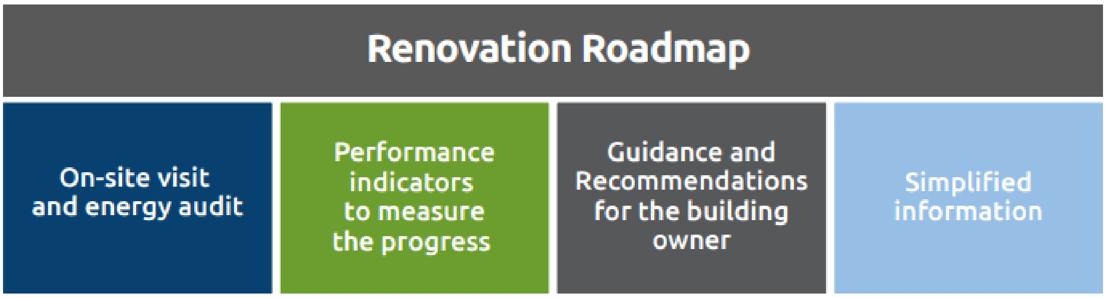

Figure 2. Key elements of a renovation roadmap. From “The concept of the individual building renovation roadmap,” by M. Fabbri, J. Volt & M.D. Groote, 2018, p. 30, BPIE – Buildings Performance Institute Europe.

An individual renovation roadmap must ensure the quality and reliability of data as well as establishing effective communication channels with the building owners (Fabbri, Volt, & Groote, 2018). As part of the iBRoad-project BPIE (Buildings Performance Institute Europe) the concept of the Individual Building Renovation Roadmap has been described, and the report outlines four key elements of the RR as shown in Figure 2. The first step being the on-site visit and energy audit and the following three steps not listed in a particular order.

From the description of the key elements based on the cases in the report by Fabbri et al. (2018) the following important steps can be outlined:

1. *Understanding the building conditions by inspecting the building and meeting with the building owners.*

2. *Discussion on potential improvements. Answering the question; what is the objective of this exercise? Personal (e.g., comfort) and policy (e.g., energy or CO2 savings).*

3. *Development of different renovation scenarios and proposal of measures to implement. Answering the question; what do we have to measure to effectively be able to implement and monitor performance improvement?*

In Figure 3 the graphic representation of the German version of a RR is shown. It shows the proposed staged renovation of a single-family house over a span of 15 years with the expected energy- and CO2-savings along with the expected cost of the renovation steps. The iSFP is offered as a help to individual building owners to support more sustainable building renovations and is a requirement to receive state funding for energy consultancy.

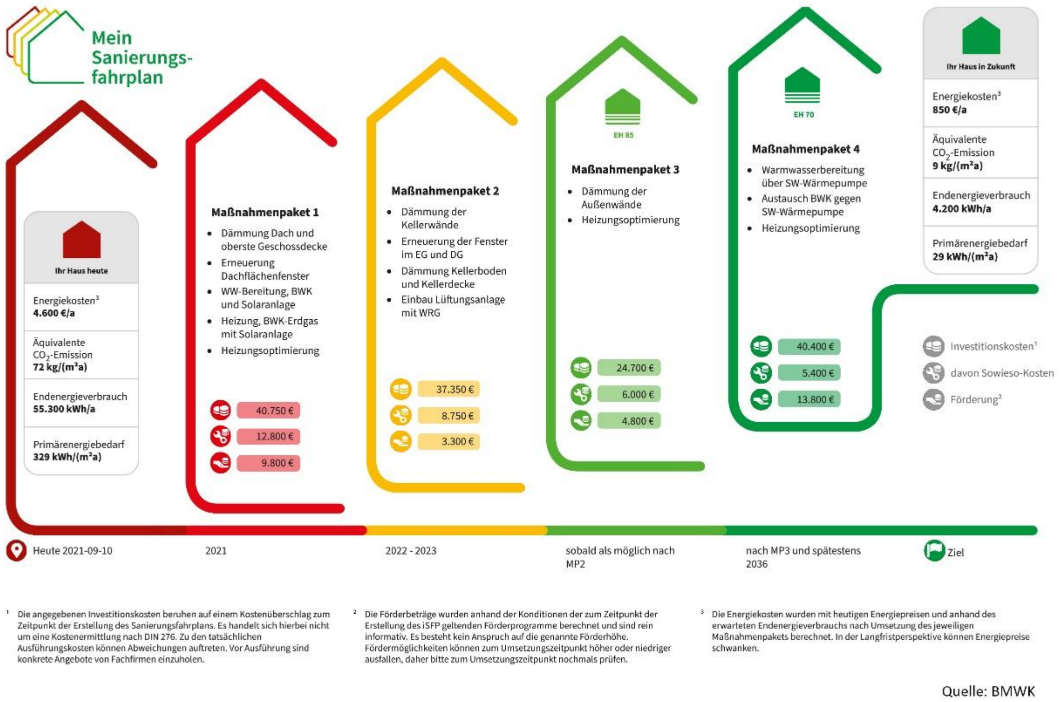

Figure 3. Graphic presentation of an individual Renovation Roadmap used in Germany. From Individueller Sahnierungsfahrplan (iSFP), by Gebäudeforum Klimaneutral, n.d. (https://www.gebaeudeforum.de/realisieren/isfp/)

A proper method for calculating the different stages of a renovation is needed to propose a sustainable building renovation. Currently the EPBD suggests the cost-optimality methodology for evaluation of proposed renovation measures. However, there is a need for a more holistic approach to the assessment of renovation stages considering also climate-oriented metrics i.e. "cumulative CO2 emissions" and social factors such as comfort requirements and budget restrictions (Maia, Harringer, & Kranzl, 2023). Maia et al. points to three important considerations for the proposal of staged renovation:

1. *The number of stages: A maximum of three are recommended, extendable up to five. (The higher the number, the longer time for achieving energy savings, and the higher risk of interruption).*

2. *Allocation (or combination) of measures (in a stage): It is especially important during implementation to avoid lock-in effects. Each technical system or building element can be seen as a stage but can also be combined with other measures.*

3. *The sequence of the stages: Defines the order in which the stage will be performed.*

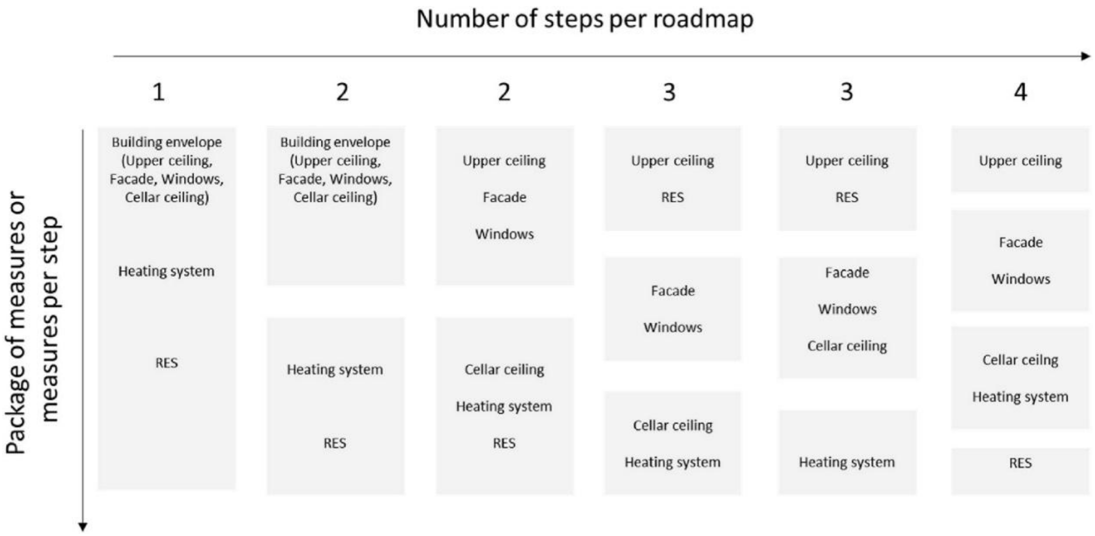

Figure 4. Different roadmap variants in terms of the number of steps and possible combination of measures per step. From "Staged renovation and the time-perspective", I.E.N Maia, D. Harringer, L. Kranzl, 2023, Smart Energy 11

A careful selection of KPIs is an important part of RRs and BRPs to evaluate the sustainability of the building renovation. According to Virta et al. (2012) a building passport can be used as a tool to evaluate sustainability if the indicators reflect both the environmental, social and economic performance of the building. In the Finnish project behind the study, the KPIs chosen were indoor environment, carbon footprint, energy and economy. The indicators and ways of measuring performance can be seen in Figure 5.

Indicator	Project phase		Operation phase	
Indoor environment	Indoor environment class (EN 15251)	A/B/C	User satisfaction (thermal comfort, IAQ, lighting and acoustics separately)	%
Carbon footprint	Life time carbon footprint (EN 15978)	$kgCO_2/m^2$	Operational carbon footprint (GHG protocol)	$kgCO_2/m^2$,a
Energy	Calculated primary energy consumption (EN 15217)	kWh/m^2,a	Measured energy use (electricity, heating, and district cooling separately)	kWh/m^2,a
			Unoccupied electricity power	kW/m^2
Economy	Life cycle cost (EN 15643-4)	€/m^2		

Figure 5. Selected Key Performance Indicators for a Building Passport in Finland. From "Building passport as a tool to evaluate sustainability of building", Virta, Hovorka, & Lippo, 2012

In the Finnish project the approach revolved around the definition of KPIs for a BP and included a "birth certificate" and a "health certificate" of a building. The "birth certificate" for a new building includes the KPIs specified during the design process. This part remains unchanged over the years until the building is refurbished. The "health certificate" is updated annually based on the real performance of a building and assists in a more efficient operation of the building for both maintenance and users. The indicators are then used to plan short- and long-term repairs and retrofitting. (Virta, Hovorka, & Lippo, 2012).

According to Fabbri et al. (2018) a RR can focus primarily on the building's energy performance or take a wider perspective including health, comfort and behavioral aspects. In the report they list the following potential indicators, but state that other indicators can be added based on local or market conditions.

Figure 6. List of main potential indicators to be included in a renovation roadmap. From "The Concept of the Individual Building Renovation Roadmap", Fabbri, M., Volt, J., & Groote, M. d., 2018

Energy performance certificates are linked to the development of renovation roadmaps as well. In 2015 the European Insulation Manufacturers Association (EURIMA) commented on the recast EPBD with a policy paper that in part suggests evolving EPCs to a building passport. EPCs should be developed into an individual renovation roadmap or building passport, which follows the building throughout its life and is linked to a Microsoft Access database and facilitates the realisation of consistent tailor-made renovation recommendations. Such a passport would include steps to undertake to achieve a targeted level of performance. Furthermore, ensuring sustainable financing mechanisms for major and ambitious actions such as deep renovation can help consumers with the up-front financing and thus implement the recommended steps in their passport (Abt, 2015).

The literature on renovation roadmaps shows examples of renovations roadmaps that are used to communicate better with end users and establish a better basis for decisions on renovations improving energy performance and indoor climate. To output useful renovation scenarios, the RR is dependent on data on the existing building including user behaviour and knowledge about the experience building performance. The renovation roadmap should therefore be able to integrate both qualitative and quantitative data. The careful selection of KPIs is important to give an output that factor in the right measurements, based on user needs, for a renovation work to be set in to action.

For proposed renovation stages fewer are better to avoid the risk of not completing the full renovation and thus achieving the energy savings planned. For the number of KPIs the amount should also be considered to make the output relevant for end users.

KPIs are an important part of both the renovation roadmap and the logbook, since the data collected in the logbook will be the data used for calculations feeding into the roadmap. The next section will give an overview of the literature on logbooks.

2.2. Logbooks

A logbook is a structured tool for recording events and information related to specific activities. Collins (2023) defines it as "a book in which someone records details and events related to something, such as a journey or vehicle". Common elements include dates, locations, descriptions, and signatures, allowing for traceability and verification. Historical examples, such as Leonardo da Vinci's notebooks, illustrate the long-standing value of systematic documentation (Roberts, 2012).

Modern logbooks have evolved into digital formats—commonly referred to as digital logbooks or e-logbooks. These electronic systems replace traditional paper records and are used across various fields to manage data more efficiently. Benefits include improved accessibility, traceability, security, and data backup. Digital logbooks capture both formal records (e.g., official documents, reports) and informal data (e.g., emails, notes, calculations). Their design and use are often shaped by industry-specific regulations to ensure accuracy, compliance, and data integrity.

An example of a digital logbook is EcoStruxure – Facility Expert. It's a digital logbook with an app-compatible format for tablets and smartphones, allowing team members to stay connected while tracking equipment maintenance. EcoStruxure tailors its online tools and products to satisfy different types of users, including building managers, service providers, panel builders, and contractors. All users have access to free collaborative digital tools for data sharing (Electric & Electric, Schneider, 2023). Each user has a defined role, enabling them to work in synchronization with each other.

The content of the digital logbook includes the following:

Operations	**Energy**
Data trends on assets	Energy consumption monitoring
Smart alerts with actionable data	Overconsumption alerts and easy identification of overload contributors
Equipment status and maintenance status	Monthly scorecards and KPIs

Collaboration features and asset details available from the field	Manual readings collection and storage
Actionable task manager with long term maintenance schedules and reminders	Energy consumption by aggregated or multisite comparison view
Edition and automatic storage of intervention reports.	Cost allocation for budget optimization

Table 1. Content of the digital logbook EcoStruxure - Facility Expert

The table above shows data taken from the Schneider Electric – Life is On Leaflet and how EcoStruxure has defined different users (actors) according to the role each performs in a company. Moreover, to access the data from the digital logbooks, a user needs to scan the QR code on the equipment and request access to upload and access documents relevant to the equipment (Electric & Electric, Schneider, 2023).

Digital logbooks are essential for recording, tracing, validating, and auditing data. The question is, "Are digital logbooks important for the AEC industry?" Nowadays, there is a need due to a lack of management and organization for building stock (Signorini, Spagnolo, & Claudio Dejaco, 2020).

Digital Building Logbooks

According to the (European Commission, et al., 2020) the definition of a "Digital Building Logbook (DBL)" is the following:

> A digital building logbook is a common repository for all relevant building data. It facilitates transparency, trust, informed decision making and information sharing within the construction sector, among building owners and occupants, financial institutions and public authorities.
>
> A digital building logbook is a dynamic tool that allows a variety of data, information and documents to be recorded, accessed, enriched and organised under specific categories. It represents a record of major events and changes over a building's lifecycle, such as change of ownership, tenure or use, maintenance, refurbishment and other interventions. As such, it can include administrative documents, plans, description of the land, the building and its surrounding, technical systems, traceability and characteristics of construction materials, performance data such as operational energy use, indoor environmental quality, smart building potential and lifecycle emissions, as well as links to building ratings and certificates. As a result, it also enables circularity in the built environment.
>
> Some types of data stored in the logbook have a more static nature while others, such as data coming from smart meters and intelligent devices, are dynamic and need to be automatically and regularly updated. A digital building logbook is a safe instrument giving control to users of their data and the access of third parties, respecting the fundamental right to protection of personal data. Data may be stored within the logbook and/or hosted in a different location to which the logbook acts as a gateway.

Figure 7. Definition - Digital Building Logbook (European Commission, et al., 2020)

The European Green Deal and the Renovation Wave have pointed out how essential is to find strategies to remove the gap between technical building information(data) of building stocks and occupant's need. To tackle this issue a research study was conducted by (Gomez, Espinosa, & Lopez-Mesa, 2022) where two DBL initiatives were selected in which several parameters were taken in consideration. Some of them included: Operation, use, stakeholders' roles, structure, user needs, definition model and functionalities. The table below outlines the initiatives and content.

Projects	Target	Study or research
iBRoad (2017-2023)	Single-family houses	Individual Building (Renovation) Roadmaps
+ALDREN (2017-2020)	Non-residential buildings (mainly hotels and offices)	Alliance for Deep RENovation in Buildings

Table 2. Projects and Study (Gomez, Espinosa, & Lopez-Mesa, 2022)

iBRoad

The iBRoad Project focuses on the renovation of single-family homes by developing a long-term digital renovation logbook tailored to the sector's specific needs. This tool integrates a range of considerations, including user requirements, financial constraints, urban development, and potential risks. Designed to offer a comprehensive overview of renovation needs within the built environment, the iBRoad logbook was piloted in three demonstration sites: Germany, France, and Belgium. Outcomes from these pilots included renovation recommendations for homeowners and the creation of Building Information Models (BIM) containing data on energy performance and accessibility (iBroad Project, 2023).

Functioning as a digital repository, iBRoad allows users to register a building by entering essential details. The logbook's repository section includes information such as location, floor area, volume, building function, and construction characteristics, offering a structured overview of the building's attributes.

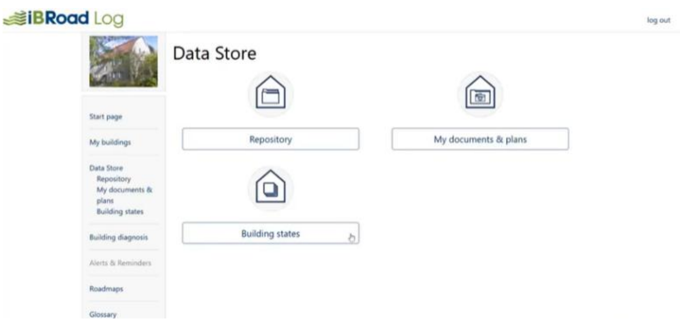

Figure 8. iBRoad Project - Main Page

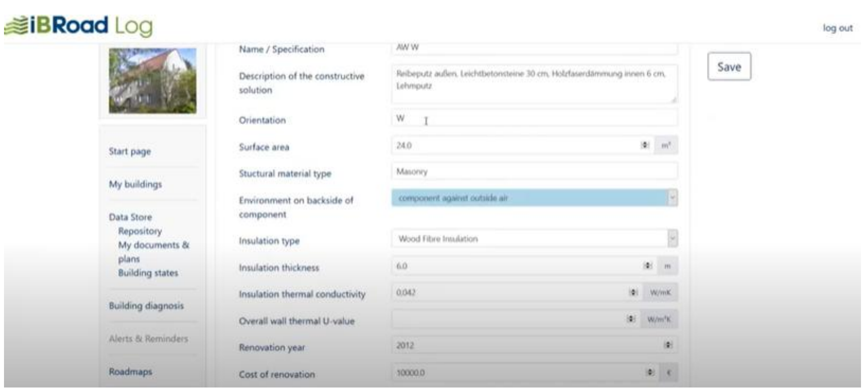

Figure 9. iBRoad Project - Building construction section

ALDREN

The ALDREN (Alliance for Deep RENovation in Buildings) project is a European initiative aimed at facilitating deep energy renovations in non-residential buildings, particularly offices and hotels. It introduces a structured methodology to guide stakeholders through the renovation process, ensuring energy efficiency, improved indoor environmental quality, and alignment with long-term sustainability goals. (ALDREN , 2023).

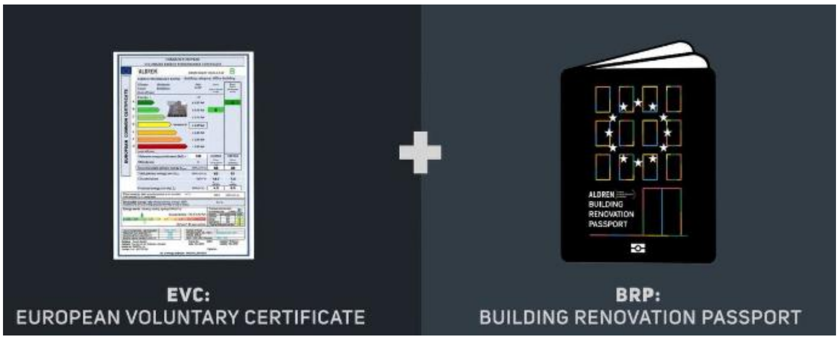

Figure 10. Two reporting modules (ALDREN , 2023).

The ALDREN Building Renovation Passport (BRP) provides a comprehensive roadmap for building renovations. It comprises two main elements:

- *ALDREN BuildLog: A detailed repository capturing the current state of a building, including technical specifications, energy performance, comfort, well-being, costs, value, and associated risks.*
- *ALDREN RenoMap: A strategic plan outlining step-by-step renovation actions, tailored to achieve Near Zero Energy Building (NZEB) standards while considering factors like cost, technical feasibility, and occupant comfort.*

The ALDREN BuildLog is the DBL that serves as a structured digital repository that compiles comprehensive baseline data on a building prior to renovation. It captures key characteristics such as architectural features, technical systems, energy performance, and indoor environmental quality. This standardized data collection ensures consistency across projects and provides a reliable foundation for assessing renovation potential.

The BuildLog enables stakeholders to document the current state of a building in a transparent and verifiable manner, facilitating informed decision-making and supporting the development of tailored renovation strategies within the broader ALDREN framework.

To ensure effective project management and support informed decision-making, the DBL is used to align with industry standards and guidelines, improving transparency, traceability, and compliance throughout the renovation process.

Digital logbook summary

Digital logbooks are increasingly recognized as effective tools for enhancing the efficiency and accuracy of record-keeping across various sectors, including healthcare, engineering, and construction.

By centralizing data management, they support improved organization, monitoring, and regulatory compliance, though their adoption may initially be hindered by the need for regular updates and resistance to change.

In the context of the built environment, digital building logbooks play a critical role in maintaining accurate and up-to-date records throughout construction and renovation processes. They facilitate the tracking of materials, energy performance, and adherence to sustainability standards, such as green certification schemes.

When integrated with renovation roadmaps, digital logbooks provide a structured framework for planning and documenting building upgrades, thereby promoting long-term energy efficiency, transparency, and resource optimization throughout the building lifecycle.

3. Development of the Renovation Roadmap

The RINNO approach in deep renovation as demonstrated in the four demo buildings was conducted with the principles of the Building Renovation Passports in mind. As such, many of the software tools and processes developed during the project aligned with the constituent components of a BRP as described in Section 2 of this report.

Regarding the design stage of the renovation of buildings, which is the stage that the Renovation Roadmap deals mainly with, RINNO involves numerous processes and provides various software tools. These collectively constitute the RINNO Planning and Design Assistant (RPDA) which enables a holistic assessment of the renovation and supports the concept of the Renovation Roadmap. The RPDA is accessible through the RINNO Platform and includes the following software tools:

- *The **Digital Twin tool**, a web-based tool developed to conduct preliminary energy analysis of the existing condition of the building as well as potential renovation scenarios based on minimum user input. This may be used for conducting a quick preliminary evaluation of the effectiveness of several renovation measures and for selecting specific renovation scenarios that may be assessed in detail with the rest of the tools.*

- ***INTEMA.building** a web-based application for conducting accurate transient building energy simulations. This tool may be used for the detailed energy analysis of the baseline (i.e., existing condition of the building) and the selected renovation scenarios and for assessing their performance based on specific energy related Key Performance Indicators (KPIs).*

- ***VERIFY**, a web-based platform designed to conduct the Lifecycle Assessment (LCA) and Lifecycle Cost (LCC) analysis on planned building renovations. VERIFY is used to estimate the environmental and cost impact of the renovation throughout the building's lifecycle, expressed in suitable environmental and financial KPIs.*

- ***Technoeconomic assessment (TEA) tool**, a desktop-based software tool developed to assess the user disruption and waste produced during the renovation. The results of the analysis are expressed in suitable KPIs which facilitate the comparison of the different renovation alternatives.*

- ***Renovation Scenario DSS***, *a Decision Support System which enables the informed decision by the user for the selection of the optimum renovation scenario out of a range of alternative ones.*
- ***Job Scheduling Optimizer (JSO)*** *is a web-based platform that supports the scheduling of a set of jobs which comprise a renovation scenario work plan.*
- ***Social-LCA tool***, *a web-based application developed to consider social aspects during a building renovation process.*

INTEMA.building, VERIFY and the TEA tool enable the holistic assessment of the renovation scenarios based on multiple performance criteria. Together with the social-LCA tools they comprise the RINNO Simulation and Assessment (RSA) toolbox. The Renovation Scenario DSS and the Job Scheduling Optimiser comprise the RINNO Renovation Optimiser and Planner which facilitates the selection of the best renovation scenario and the optimum sequence of works according to the user's preferences. Furthermore, RINNO involves novel techniques for capturing and mapping the existing condition and developing the BIM model of the buildings.

The main RINNO processes compliant to the development of the Renovation Roadmap are described in the following paragraphs.

3.1. On-site data gathering and auditing

As part of the RINNO project, the renovation of the buildings needed to meet specific performance goals in terms of energy and CO2 savings. To achieve this, it was crucial to first establish the baseline energy performance, which involved assessing the existing condition of the building. This required conducting a detailed survey of the buildings and gathering data on the building envelope and systems prior to the renovation. The data collection process included:

- *Documenting the building geometry and creating accurate BIM models for each demo building.*
- *Gathering information on the materials used in the building envelope, with input from demo leaders and associated design teams.*
- *Collecting details on building systems responsible for heating, ventilation, air conditioning (HVAC), and domestic hot water.*
- *Investigating any renewable energy systems that were in operation before the renovation.*

The development of the BIM files, which include data on the building geometry and materials was undertaken as part of Task 3.1. In the Greek, Polish and French demos 3D scanning of the buildings was conducted; the resulting point cloud which represents the shape of the building through the 3D scanning was then converted into the BIM model (in .ifc format). An example of the 3D scanning output and the subsequent BIM for the French demo is shown in Figure 11. The Pilot Site Survey where information regarding the building materials, HVAC systems and RES was carried out under Task 1.3, with findings reported in Deliverable 'D1.5 - RINNO Pilot Analysis and Deployment Plan (Final Version)'.

Figure 11. 3D scanning (top) and BIM model (bottom) of the French demo

3.2. Definition of renovation targets and alternative renovation scenarios

The next step of the process involved defining the specific requirements of the users i.e. the demo leaders from the renovation as well as the specific performance targets that the buildings should meet in terms of energy, environmental performance taking into consideration aspects regarding thermal comfort and occupant well-being. A thorough investigation of the specific requirements of the end-users was conducted in Task 1.1 and reported in Deliverable D1.2 - RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (Final Version).

Having set the specific requirements for the renovation as well as the specific targets in terms of the buildings' expected performance post renovation, the next step involved the definition of the potential renovation scenarios. Within Task 1.3 the demo leaders in collaboration with other RINNO partners analysed characteristics of each demo building, taking also into consideration the country-specific conditions (climate, local regulations, site restrictions etc.) and defined renovation actions suitable to each of the buildings. This process resulted in the definition of the various alternative renovation scenarios in a qualitative (i.e. descriptive) manner. These were then examined with the use of the RINNO Planning and Design Assistant tools to quantify and finalise them. At first, the energy performance of various renovation measures was examined with the use of the Digital Twin tool on a preliminary basis and the scenarios were defined quantitatively (Figure 12). Next the performance of these scenarios was assessed in detail in terms of their energy, environmental and cost performance as well as in terms of the expected user disruption and waste produced with the use of the RINNO Simulation and Assessment toolbox (INTEMA.building, VERIFY, TEA tool).

	Space heating			Hot water			Appliances and lighting electricity			Space cooling		
Delivered/Local production	Delivered kWh/a	Delivered kWh/m2,a	Local_prod. kWh/a	Delivered kWh/a	Delivered kWh/m2,a	Local_prod. kWh/a	Delivered kWh/a	Delivered kWh/m2,a	Local_prod. kWh/a	Delivered kWh/a	Delivered kWh/m2,a	Local_prod. kWh/a
Before	204328	136	0	45306	30	0	31795	21	0	0	0	0
After	24326	16	49138	13093	9	20949	23906	16	7889	0	0	0
Savings	180002	120		32213	21		7889	5		0	0	

Primary energy analysis			
	Baseline kWh/a	After renovation kWh/a	Savings kWh/a
Delivered primary energy for heating:	204328	62760	141568
Delivered primary energy for cooling:	0	0	0
Delivered primary energy for hot water:	116890	33780	83110
Delivered primary energy for appliances/lighting:	82032	61678	20354
Total delivered primary energy:	403250	158218	245032

Installed refurbishmen measures:
A2. Installing new ventilation system -- Estimated annual mechanical air flow is 100.0 % from original.
A5. Sealing the envelope -- Estimated annual Infilatration air flow is 59.0 % from original.
B2. Replacement of windows with improved thermal performance (U-value) -- The U-value has changed from 5.6 to 1.4 [W/m2,K]. Total estimated window area is 117.0 m².
B5. Replacement of windows with a new type (G-value) -- Window glazing has changed from SINGLE to SELECTIVEDOUBLE. Total estimated window area is 117.0 m².
C2. Insulation of outside walls -- U-value changed from 2.15 to 0.2 [W/m2,K]. * K-FLEX (λ=0.025 W/mK) insulation thickness needed is around 114.0 mm. * EKOLAB (λ=0.037 W/mK) insulation thickness needed is around 168.0 mm.
E2. Improving heat insulation of the upper floor -- U-value changed from 0.33 to 0.16 [W/m2,K]. * K-FLEX (λ=0.025 W/mK) insulation thickness needed is around 81.0 mm. * EKOLAB (λ=0.037 W/mK) insulation thickness needed is around 120.0 mm.
J8. Main space heating, air to water heat pump -- Annual delivered main space heating energy is 12.0 % from the original. Local production is 67.0 % from the demand of 73464.0 kWh. Auxiliary space heating demand is 0.0 kWh.
M8. DHW Air to water heat pump -- Annual delivered domestic hot water heating energy is 29.0 % from the original. Local production is 62.0 % from the demand of 34042.0 kWh. Auxiliary hot water heating demand is 0.0 kWh.
N11. Installation of pv panels, production target 25% -- Estimated areas for PV panels to cover the target. **Appliance electricity**, local production is 7890.0 kWh/a. * PV roof panels (efficiency: 19.0 % , system loss:14.0%, directed: south, slope: local latitude). Estimated annual solar radiation is 1121.0 kWh/m2. Area needed to reach the target is around 44.0 m². * PV wall panels (efficiency: 14.0 % , system loss:14.0%, directed: south, slope: 90 degrees). Estimated annual solar radiation is 792.0 kWh/m2. Area needed to reach the target is around 83.0 m². **All delivered electricity**, production target is 17244.0 kWh/a. * PV roof panels (efficiency: 19.0 % , system loss:14.0%, directed: south, slope: local latitude). Estimated annual solar radiation is 1121.0 kWh/m2. Area needed to reach the target is around 95.0 m². * PV wall panels (efficiency: 14.0 % , system loss:14.0%, directed: south, slope: 90 degrees). Estimated annual solar radiation is 792.0 kWh/m2. Area needed to reach the target is around 181.0 m².
O2. Insulating hot water heating system pipes -- Hot water circulation pipe losses from 8.0 to 2.0 kWh/m²,a

Figure 12 Results view of the Digital Twin tool where various renovation scenarios are defined

3.3. Definition of KPIs to measure performance

To support the selection of the optimum Renovation Scenario DSS, a set of Key Performance Indicators were defined. These KPIs are the outcome of the holistic analysis conducted by the RINNO Simulation and Assessment (RSA) tools, namely INTEMA.bulilding, VERIFY and the TEA tool, and represent the user requirements as defined in Deliverable 'D1.2 - RINNO Requirements and Renovation Technology Catalogue and Roadmap to TRL9 (Final version)' as well as the performance targets set for each building. The following KPIs are included in the selection:

- ✓ *Yearly Lifecycle Life Cycle Global Warming Potential savings*
- ✓ *Yearly embodied energy*
- ✓ *Yearly water footprint*
- ✓ *Average daily project waste*
- ✓ *Overall project waste*
- ✓ *Yearly Energy Self-Supply by RES*
- ✓ *Yearly Primary energy savings – PES*
- ✓ *Decrease in Energy Consumption*
- ✓ *Savings in Primary Energy consumption for heating*
- ✓ *Savings in Primary Energy consumption for cooling*
- ✓ *Savings in Primary Energy consumption for DHW*
- ✓ *Increase in RES based electricity production*
- ✓ *Increase in RES based thermal energy production*
- ✓ *Return on Investment*
- ✓ *Payback period*
- ✓ *Yearly Lifecycle Cost Savings*
- ✓ *Initial Investment (CAPEX)*
- ✓ *Annual O&M Costs*
- ✓ *Average Daily Disruption (UTILITIES)*
- ✓ *Average Daily Disruption (TRAFFIC)*
- ✓ *Average Daily Disruption (PHYSICAL SPACE)*
- ✓ *Average Daily Disruption (INTERNAL ENVIRONMENT)*
- ✓ *Project Duration*

The KPIs are grouped into four categories, namely: energy, environmental, cost, and financial and user disturbance. The user then sets their preferences by selecting the KPIs to be included in the analysis and specific weights in each category and the Renovation Scenario DSS determines the best renovation scenario out of several alternatives that meets the user specifications and needs. Having selected the best renovation scenario according to their preferences, the users may then proceed to the scheduling of the renovation works of the selected scenario with the use of the Job Scheduling Optimiser (JSO), the planning module of the RINNO Optimiser and Planner.

3.4. The Renovation Roadmap

With the use of the RPDA tools the optimum renovation scenario that meets the requirements of the user, and the energy efficiency targets has been defined. To support staged renovation, RINNO also delivers a Renovation Roadmap where long-term renovation paths with specific steps are proposed to the user for the selected scenario. This is to provide an alternative option to the user in conducting deep renovation when available funding is not sufficient for the whole renovation at once and hence support the wider uptake of deep renovation projects.

Following findings and recommendations from literature (Maia et al. (2023)), a roadmap considering three renovation steps is provided to the user. In each step, the renovation measures considered, the associated primary energy savings and CO2 and capital costs are presented to the user as well as the operational costs of the building after the completion of each step (Figure 13).

The information required for the delivery of the Renovation Roadmap is provided by the various tools of the RPDA. At first the JSO imports the main renovation jobs of the scenario as well as their specifications from the Technoeconomic Assessment (TEA) tool. Each job represents a specific renovation measure for which the load reductions achieved have been determined by the INTEMA.building tool. VERIFY then calculates the Primary Energy savings and CO2 emissions savings for each job by considering the relevant Primary Energy Factors and CO2 emissions factors. Furthermore, the operational cost savings are also determined by considering the energy savings and the relevant fuel and electricity prices. At the final step JSO groups together jobs in specific renovation steps and determines the overall primary energy savings, emissions savings and operational cost savings along with the overall cost of the renovation steps by aggregating the respective values of all the jobs involved.

The grouping of measures in steps was done using a methodology which considers:

- ***Prioritization of measures.*** *Load reducing measures (such as window replacement, insulation for walls, roofs, and floors, as well as mechanical ventilation systems) and RES systems were considered to have highest priority than replacement of active HVAC systems. Following a fabric first approach, where upgrading the building envelope aims to minimize thermal losses, load-reducing measures were given the highest priority, followed by the active measures. Such a strategy reduces the risk of installing an HVAC system before insulating the building, which could then lead to an oversized and inefficient system. Additionally, photovoltaic systems were also prioritized due to their ability to provide savings without affecting heating or cooling load reductions. Hence, the installation of heating and cooling systems is considered after the installation of the passive and the RES systems.*

- ***Setting an appropriate sequence and grouping of measures of the same level of priority to define the various steps.*** *The sequence and grouping of measures of the same level of priority in specific steps was conducted considering:*

    1. *Similarity of application area, and*
    2. *relevant primary energy and cost savings. Measures which target the same building area and provide significant primary energy and cost savings have been grouped in the same renovation step.*

- ***Avoiding lock-in effects.*** *Measures which are mutually dependent on each other have been grouped in the same step to avoid any repetition of work at a later stage if this is considered separately.*

- ***Considering measures of increased complexity and low cost-benefit ratio at the last step.*** *This involves the insulation of the floor slab and replacement of the heating/cooling system (as a fabric first approach was followed).*

The measures considered include general common renovation measures implemented in renovation projects, namely insulating the building envelope (walls, roof, floor), replacing inefficient windows with energy efficient ones, installing mechanical ventilation system, replacing old inefficient HVAC systems with energy efficient ones and installing PV systems on the roof, façade of the building or the ground to produce renewable energy. These measures were then examined and ranked in terms of complexity for implementation taking also into account interdependence between the various measures.

Following the above methodology, the following grouping of measures was considered, leading to the specific renovation steps:

A. *Insulation of walls, windows replacement and insulation of heating distribution pipes is considered in one step. These measures achieve high PE and cost savings.*

B. *Insulation of ceiling and RES system installed on the roof is considered as a separate step. These measures consider the same application area and achieve high PE and cost savings and are mutually dependent, therefore have been considered in the same step.*

C. *Insulation of floor is a difficult renovation measure with high complexity and therefore this is considered as the last step of the renovation. In addition, replacement of the HVAC system is also considered in this last step as the active systems were assigned a low priority.*

It should be noted that Points A and B above may both achieve high PE and cost savings and may be conducted independently of each other. Therefore, it was considered that both these steps could be assigned a first and/second priority whilst point C was considered always as a third step. For this reason, the roadmap considers two renovation routes where points A and B above were used interchangeably as Step 1 and Step 2 whilst Point C measures are considered as the third renovation step. An example of two alternative renovation roadmaps is provided in Figure 13 below. In this Figure, the renovation is shown in distinctive steps depicted as houses with distinct colors. The baseline condition of the building is shown as a red house. The values of the Primary Energy Demand (kWh), the CO2 emissions and the operational cost of the baseline are shown inside the house. The renovation steps are then presented as a yellow (Step 1), light green (Step 2) and dark green (Step 3) house. Inside each house, the capital cost of the measures is shown along with the Primary Energy Savings, the CO2 emissions savings, and the cost savings for that step. The renovation measures considered in each step are presented below the respective house. The green box at the tight-hand side of the image shows the overall primary energy and CO2 emissions savings that may be achieved with the full renovation as well as the overall cost of the renovation and the resulting operational cost.

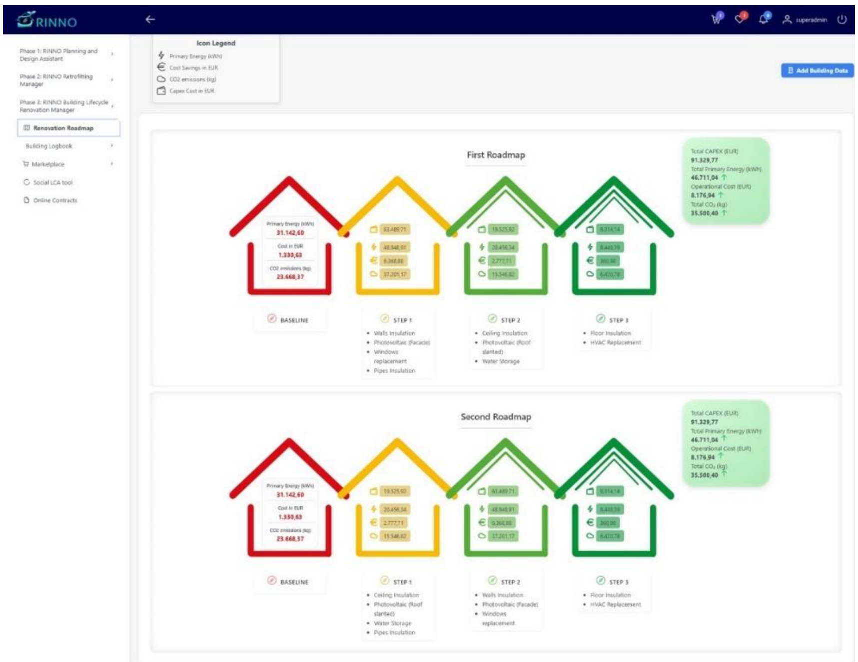

Figure 13: The RINNO renovation roadmaps for supporting staged renovation.

3.5. Logging the Building Data

Apart from delivering the two alternative renovation paths, the RINNO Renovation Roadmap also enables the user to enter various static data regarding the building, its systems as well as general information. To do so, the user may click on the 'Add Building Data' button on the main page of the Renovation Roadmap (Figure 13). A pop-up window is then presented where the user may enter either:

1. *Administrative Information on the building*
2. *General building Information*
3. *Building Element information*

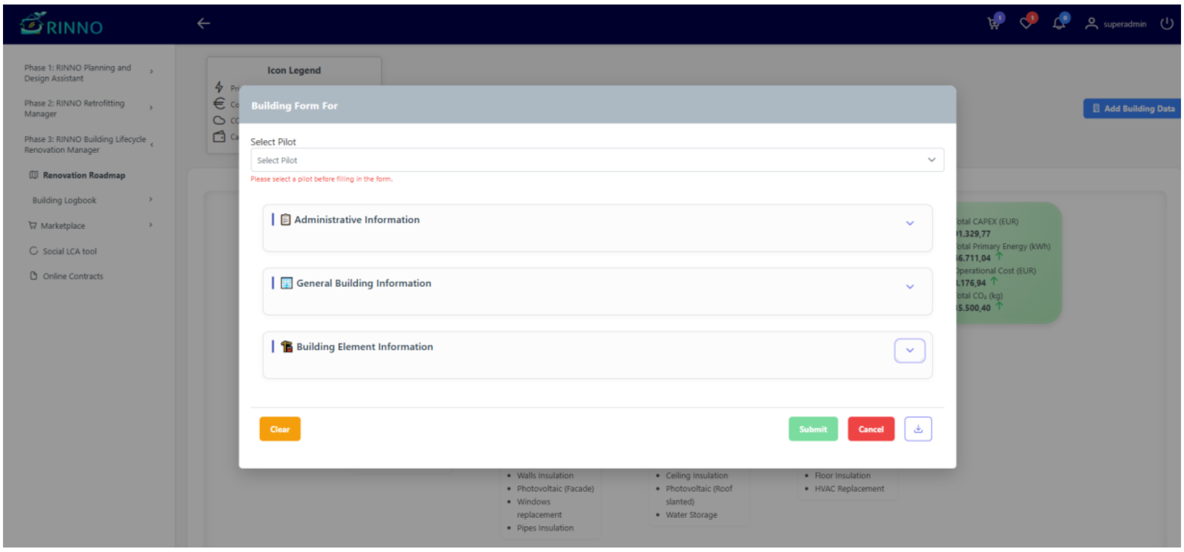

Figure 14: Main window for the user to enter information regarding the building

Administrative information includes information regarding the building name and type (residential (single family), residential (multifamily), office, educational, hotel and other), location (latitude, longitude, address) as well as information on the type of owner (physical person, company where multiple owners may be selected) and ownership type (sole ownership, co-ownership) and the name of the owner (s) as shown in Figure 15 below.

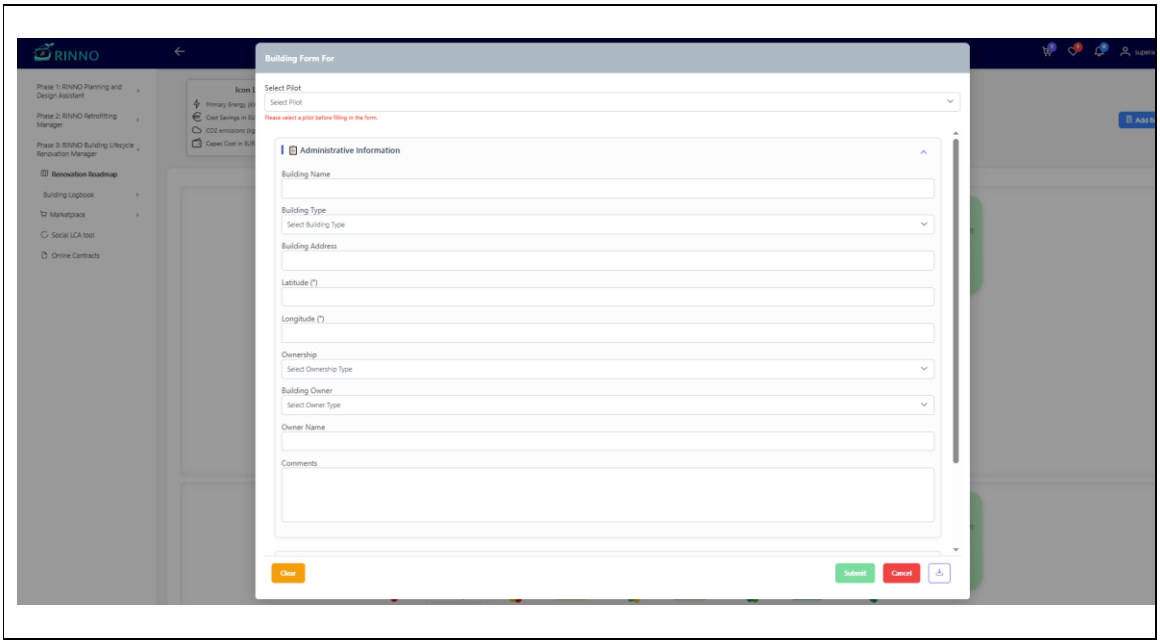

Figure 15: Administrative Information form

General Building Information may be entered by clicking the relevant button which then opens a relevant form where the user may enter the following information:

- *Year of construction*
- *Status of the building (new-built, existing, renovated)*
- *Year of renovation (if applicable)*
- *Envelope components and building systems that have been renovated in the past (if applicable)*
- *Description of the renovation (if applicable)*
- *Number of storeys*
- *Building height*
- *Footprint and heated area*
- *Construction type (masonry, timber frame, steel frame etc.)*
- *Type of roof (flat, gabled, hipped) and roof inclination*
- *Access to District Heating*

The relevant form is shown in Figure 16 below

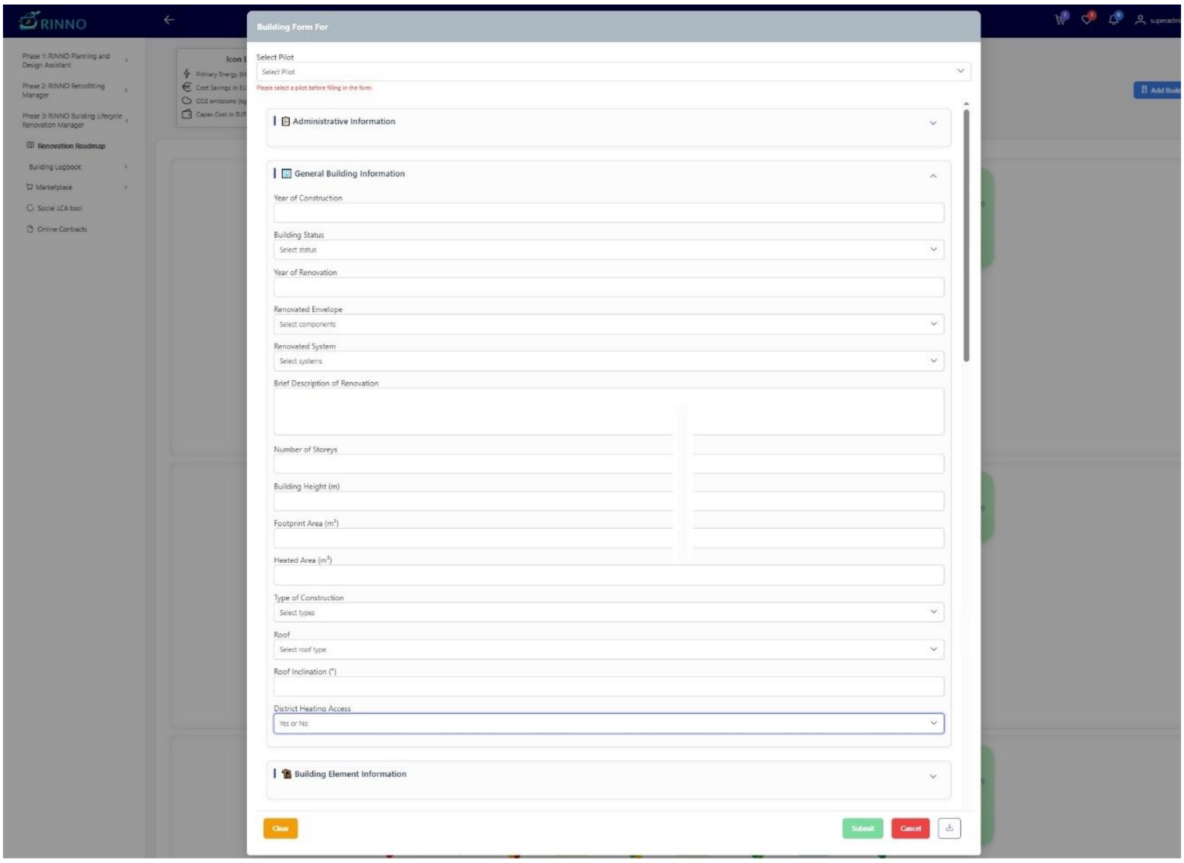

Figure 16: General Building information form

The form for entering Building Element information includes data on building envelope components, HVAC systems as well as RES systems to produce electricity and thermal energy. More specifically it includes information on:

- *Walls (construction, materials, U-value). The user may specify one or more types of walls.*
- *Floors (construction, materials, U-value). The user may specify one or more types of floors.*
- *Roofs (construction, materials, U-value). The user may specify one or more types of roofs.*
- *Windows (construction, materials, U-value). The user may specify one or more types of windows.*
- *Space Heating system (type, i.e. boiler, heat pump etc., energy source and efficiency). The user may specify one or more types of space heating systems.*
- *Domestic Hot Water system (type, i.e. boiler, heat pump etc., energy source and efficiency). The user may specify one or more types of DHW systems.*
- *Cooling system (type of heat pump and COP). The user may specify one or more types of cooling systems.*
- *Mechanical Ventilation System (type of system, i.e. supply, extract, balanced, etc, power consumption and heat recovery efficiency). The user may specify one or more types of*

ventilation systems.

- *Lighting System (type of system, i.e. LED lightbulbs, fluorescent tubes etc. and lighting control system, i.e. photosensors, occupancy sensors). The user may specify one or more types of lighting systems.*
- *Photovoltaic system (type of placement, i.e. roof, façade or ground, battery type, i.e. Li-ion or Led-Acid and installed capacity in kW). The user may specify one or more types of PV systems.*
- *Solar thermal systems (type of collector, i.e. flat plate, evacuated tube or unglazed, collector area, pump power, storage tank capacity, tank insulation material, insulation thickness and/or U-value). The user may specify one or more types of PV systems.*

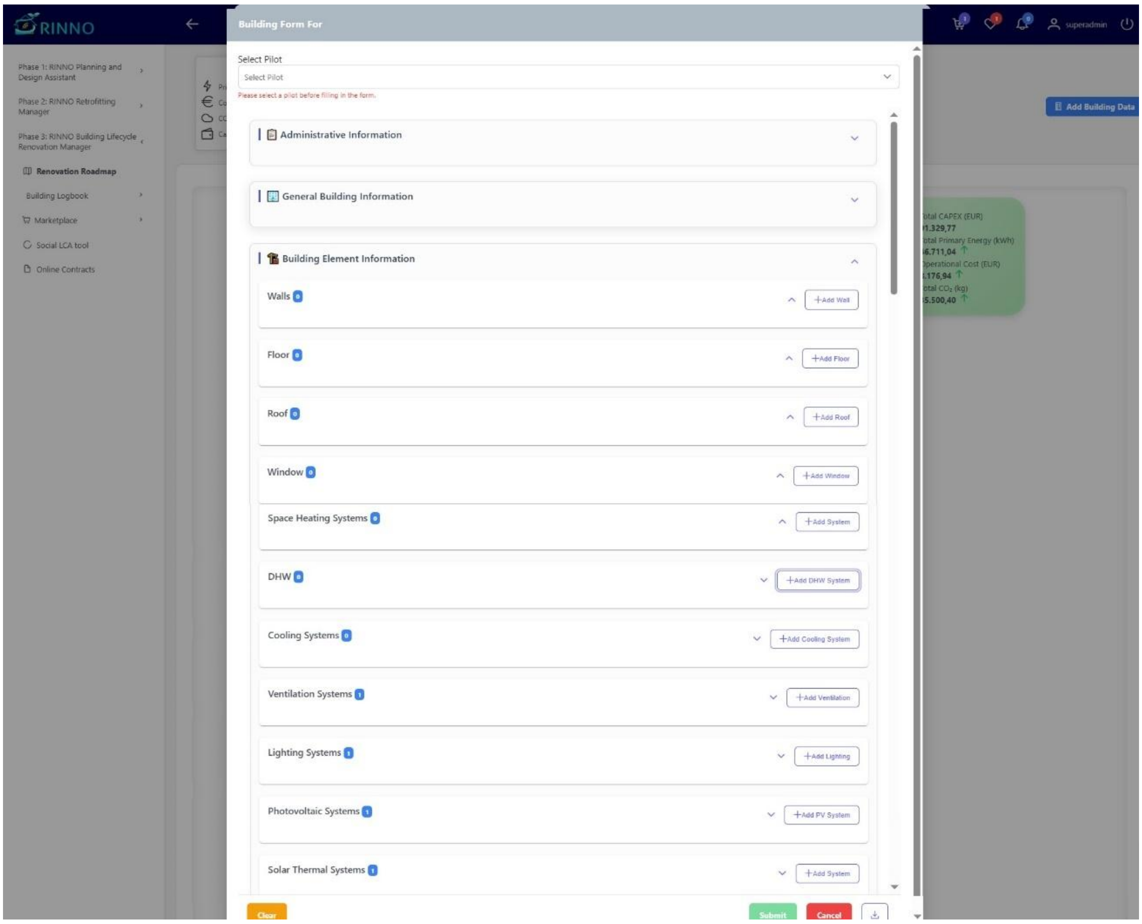

Figure 17: Building Element information form

4. Logbook creation

Creating a comprehensive logbook is a crucial aspect of managing the renovation project across the four European countries: Greece, France, Poland, and Denmark. The logbook serves as a central repository of information, facilitating the efficient tracking and monitoring of various building-related parameters, the integration of advanced technologies, and the effective coordination with third-party stakeholders. This section outlines the key components of the logbook, segmented into building-related information, technologies for real-time management and monitoring, and linkage to third parties.

Figure 18: Flowchart depicting the logbook system, showcasing data collection, processing, user interactions, and reporting for efficient building management.

The foundation of the system is the Pilot Site Sensors. Specially installed sensors at each site deliver precise information on usage of energy, environmental conditions, user comfort, and additional cost-driver parameters. It offers the localized measurement that enables customized feedback aligned with the unique operational dynamics of a site.

Data captured by the sensors gets forwarded to Edge Devices, the initial aggregation points of the data. The devices receive the incoming data and prepare the data in the proper form for further examination and logging.

The central hub of the system is the Logbook where one documents and stores crucial records. In the logbook, two classes of information are stored:

- *Event Types: These include sensor logs, system alerts, and other significant events that should be tracked.*

- *Maintenance History: All past maintenance work, repairs and routine maintenance are kept on record to have a full history of building maintenance.*

Data processed before permanent storage occurs during a Data Processing stage. Validation of accuracy and aggregation for bringing together the relevant points of data in a singular location occurs within this process. Processed data becomes the means by which the integrity of entry information within the system is preserved.

The processed information is securely stored within a Data Storage system consisting of a centralized database as the most prevalent type. It supports retrieval of past logs for examination, analysis, and reporting.

The application supports multiple user dashboards for diverse roles:

- *Admin Dashboard: Offers the administrator a view of the user activity and system operation for effective management and monitoring.*

- *Operator Dashboard: It is intended for day-to-day monitoring. It enables the operator to see activity that is happening currently, troubleshoot immediately on the spot, as well as engage interactively with the logbook.*

User Actions captures the user activity within the system. It records logging activity, search history, and new information entry, providing a complete monitoring of activity.

The system also possesses strong Reporting functionality. The recorded events and maintenance history summaries may be produced by the users for the purposes of decision-making using facts and for planning at a strategic level.

The system also comprises a Notifications functionality that informs the user of significant occurrences, reminders for scheduled maintenance work, and anomalies within the monitored settings. The anticipatory notification pre-empts issues before they arise.

4.1. Building-related information

The logbook collects and maintains detailed building-related information for each of the renovation projects across Greece, France, Poland, and Denmark. This includes:

- ***Building documentation****: Apart from the information that the user may enter manually through the renovation roadmap, the user may also upload relevant documents of the building to the logbook repository. This may include the building's BIM file, drawings, Energy Performance Certificate, permits, pictures as well as any other documents that demonstrate the building's history of changes. This may be done through the relevant section of the Building Logbook (Figure 19).*

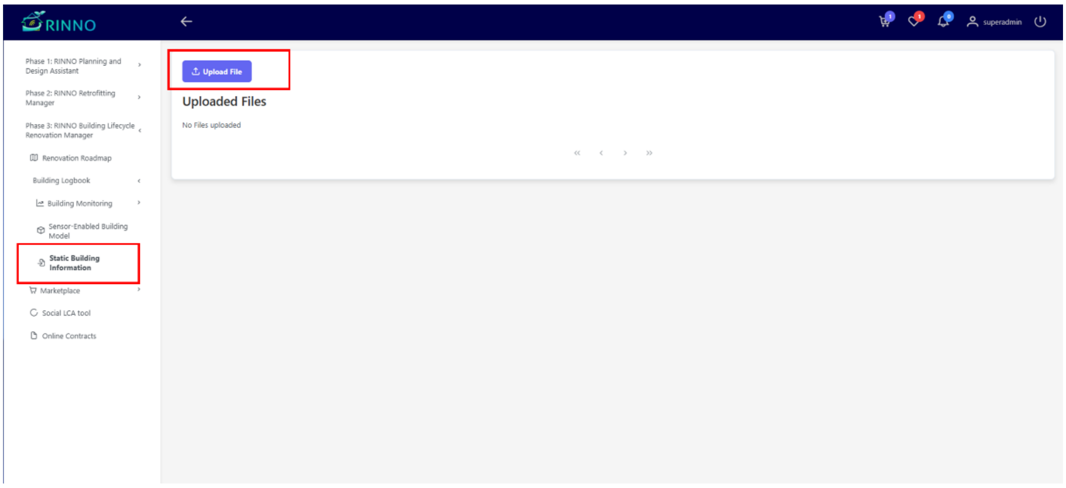

Figure 19: Logbook functionality for uploading building documents

- ***Baseline Data****: Initial assessments of the buildings, including current energy performance metrics, insulation quality, heating, ventilation, and air conditioning (HVAC) system efficiency, and existing levels of comfort (e.g., temperature, humidity).*

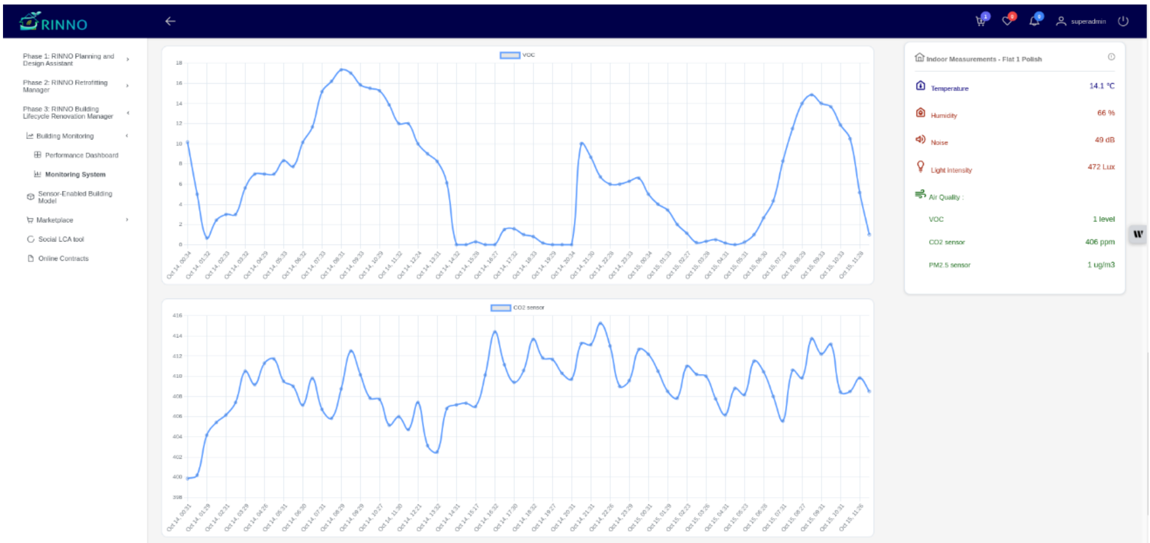

Figure 20. Illustrating varying levels of occupant comfort

- ***Sensor Data Integration****: Continuous data from installed sensors capturing key environmental and operational metrics such as temperature, humidity, CO2 levels, particulate matter, and noise levels. This data provides real-time insights into indoor air quality and comfort levels, which are critical for optimizing renovation outcomes.*

- ***Energy Consumption****: Detailed energy usage data, broken down by source (electricity, gas, renewable energy), time of day, and specific building zones. This helps in identifying energy-saving opportunities and tracking the impact of renovation interventions on energy efficiency.*

- ***Performance Dashboard**: Aggregated comparison of pre-renovation baseline energy use, projected consumption under renovation conditions, and actual post-renovation performance. The analysis covers total energy sources (renewable, electricity, gas) and examines usage patterns by time of day and season. This approach allows for accurate quantification of energy savings and provides clear validation of improvements in energy efficiency resulting from the renovation efforts.*

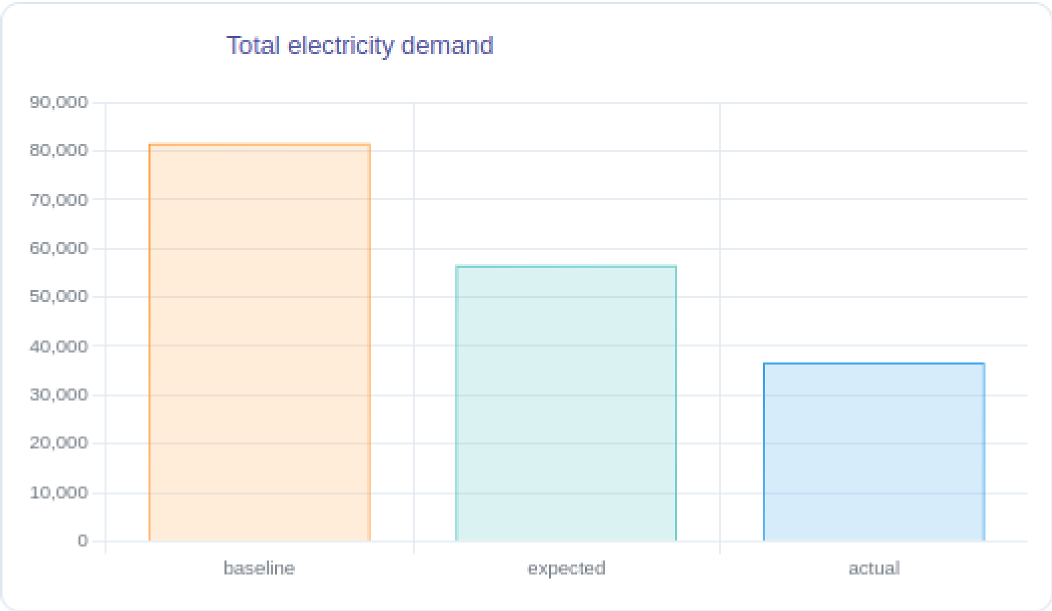

Figure 21. Comparative analysis of pre-renovation consumption, projected demand under the renovation scenario, and post-renovation energy performance.

4.2. Technologies for managing and monitoring in real time

The use of advanced technologies is essential for real-time, effective management and monitoring of renovation projects. The logbook compiles data from various technological tools and digital platforms, serving as a central hub for overseeing and coordinating the renovation process. It facilitates the monitoring and control of different building systems, including HVAC, lighting, energy usage, and other critical operational components. New generations of monitoring systems contribute to enhanced operational efficiency, reduced energy consumption, and improved indoor comfort.

This section provides a detailed explanation of the specific technologies and methods integrated into these systems, including REST API-based platforms, real-time monitoring through MQTT servers, and software equipped with rule-based engines that generate alerts and maintenance notifications.

- *REST APIs enable BMS to integrate and communicate with all other sensors, devices, and software platforms within the building. REST APIs enable BMS to connect all subsystems in the buildings to allow access to the data collected and sent to and from different building subsystems such as HVAC units, lighting controllers, and energy meters. Such capability provides real-time monitoring and control among all connected devices. This capability provides REST APIs to third parties to use or integrate applications and devices, thereby allowing the BMS to be adaptive and* *flexible towards innovations. This capability is particularly relevant for a multi-country project in which different standards and technologies have been used. REST APIs provide a scalable framework that allows the BMS to easily enlarge its operations or functionality with the addition of new devices or optimization of the building systems.*

- *MQTT is a lightweight messaging protocol for efficient yet simple real-time monitoring and control of building systems. Because it is fast and efficient, it sends messages to deliver the most important real-time monitoring of critical parameters, including temperature, humidity, CO2 levels, and energy consumption. The publish/subscribe model of MQTT allows the BMS to serve significantly higher numbers of sensors and devices without such an enormous impact on the network load that would permit extensive buildings to be fitted with it. Finally, it allows reliable data message delivery, even across unstable network connections, which is crucial for consistent monitoring and reaction to conditions changing very quickly.*

The monitoring software also integrates rule-based engines allowing building managers to establish conditions upon which alerts will be triggered. Thresholds for parameters such as temperature exceeding a defined level, unusual energy consumption behaviour, or CO2 above safe levels can be set by users. Unfortunately, once a threshold is crossed, an alert within the system is automatically triggered. Not only does this engine provide alerts, but it can also set up parameters for behaviours, such as changes in HVAC configurations, dimming the lights, and starting backup systems, making the building even more responsive to real-time factors and situations. Alerts can be configured to be sent via push notifications, or via the monitoring system dashboard to make sure the right personnel are informed in a timely manner.

This predictive maintenance software is an extension to the real-time monitoring data and analytics which can be utilized for anticipating equipment requirements. Such trends can help the system infer from sensor data when equipment is going to fail or is in need for servicing. So, maintenance can be scheduled in a preventive way, minimizing downtime and maximizing the life of building systems. Maintenance activities notifications can be generated based either on preestablished schedules or on detected anomalies. For example, it can notify professionals once HVAC filters need to be changed or if one of its components is not performing according to its normal operating range.

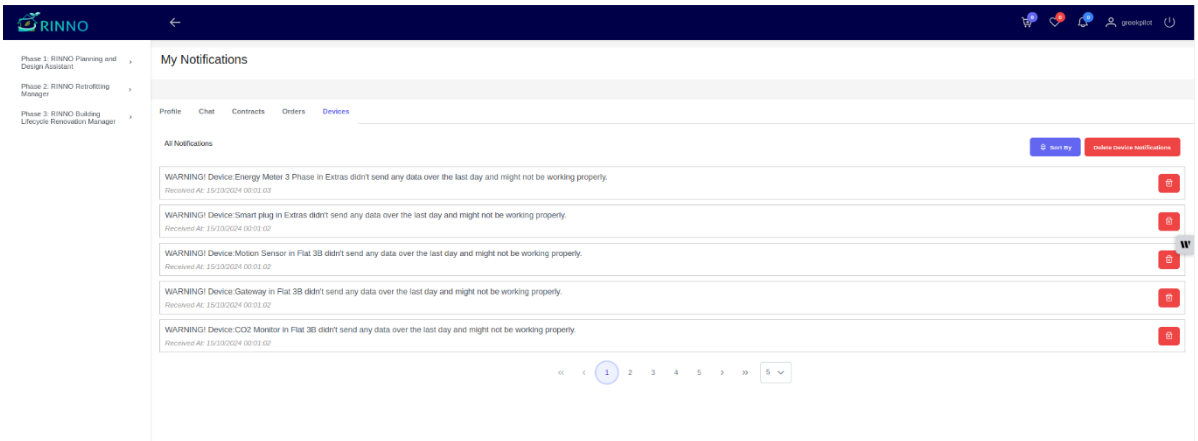

Figure 22. Sensor data enables the system to detect when equipment is likely to fail or require servicing, allowing timely maintenance. The Internet of Things (IoT) makes it feasible to monitor and optimize energy consumption in built environments in real time through the deployment of able sensors into gathering

continuous data measurements regarding environmental conditions (temperature, humidity, CO2 levels), energy consumption, occupancy trends, and other relevant metrics.

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Thus, these results serve as entry into an analytical platform, giving trends and predictive maintenance notifications.

Also, this is the one that can advise real time and monitor energy consumption. Healthy thresholds for help meet can be predefined, such as not on a given day or hour to trigger notification sounds to remind owners to turn off the heating or cooling units in rooms not occupied and maximize energy savings.

Thus, it might include using digital means to replicate buildings in virtual ways for stakeholders to test renovation scenarios, predict effectiveness, and pre-optimize designs before construction, as well as ultimately contribute towards performance monitoring once renovation is completed.

All sensor data, any energy metrics, and any metrics relating to the buildings are kept safe in an encrypted database, which makes access easy for stakeholders across different countries to share data and collaborate seamlessly. Linkages to Third Parties. The logbook facilitates all linkages to relevant third-party stakeholders such as contractors, regulatory bodies, energy suppliers, consultants, technology providers, financial partners, facility managers, and building occupants.

The RINNO Suite highlights the use of Hyperledger as a core tool for securely managing and tracking detailed records throughout the renovation process. All data regarding contractors and subcontractors, such as their scope of work, timelines, and compliance with contractual obligations, are thus stored securely. The system also tracks the communication, deliverables, and performance metrics of all involved, creating transparency and accountability.

Hyperledger creates space for including local regulatory bodies and documenting interactions with them for compliance with building codes, with environmental regulations, and with legal requirements in different jurisdictions. It maintains a secure log of interactions and transactions with various stakeholders.

The logbook, with its structured approach to collecting, managing, and sharing data, serves as a pivotal tool in ensuring that the renovation projects in Greece, France, Poland, and Denmark are executed efficiently, sustainably, and in alignment with stakeholder expectations.

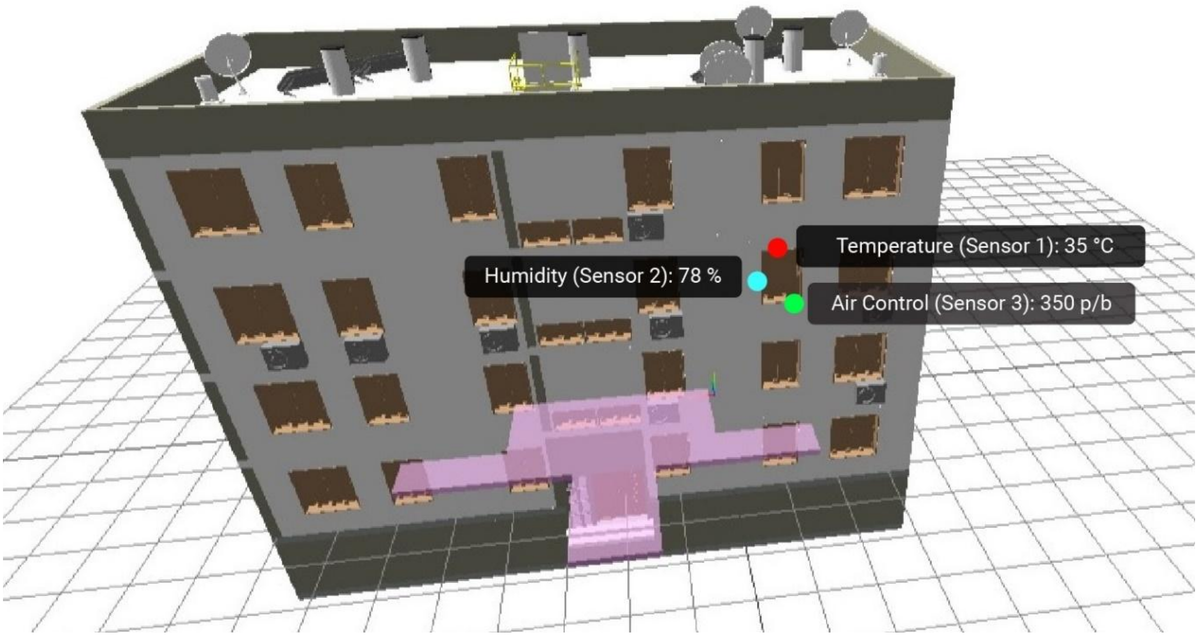

Figure 23. Metrics and alerts dashboard displaying real-time monitoring of building conditions and performance.

5. Full-scale demonstration projects

In this work package the RINNO tools are matched with requirements for a Building Renovation Passport. The methodology of the BRP has been developed using data from the four RINNO pilot sites, and the full-scale demonstration projects then serve as a testbed for the approach and tools developed within the project.

In this chapter experiences from development and implementation of scenarios for staged renovation and a digital building logbook are communicated and presented as guidelines for future development and use.

5.1. Experiences and results

The RINNO Building Renovation Passport consists of a Renovation Roadmap and Digital Building Logbook (Figure 24). The Logbook stores real time data and baseline input and it is possible to access information about the current state of the building. In the renovation roadmap the possible scenarios for stage renovation are calculated and presented using results for the KPIs shown in the figure.

A methodology for calculating renovation steps in the renovation roadmap have been developed in the RINNO-project. There is no standardized way of doing this. The experience in the project is, that at more standardised selection of methods to consider in each renovation passport step is needed to compare across different BRP-tools and to align expectations for users and professionals.

The renovation roadmap requires significant investments in tool / software development and acquisition. The RINNO platform offers a tool that combines energy analysis, LCA and LCC linked to the relevant KPIs, as well as a methodology defining the steps.

A detailed initial audit of the building is required to assess the current conditions of the building. This has been carried out as part of the RINNO-project on the pilot sites using 3D-scanning. 3D-scans are a promising tool to verify floorplan layouts and understand changes made to the building.

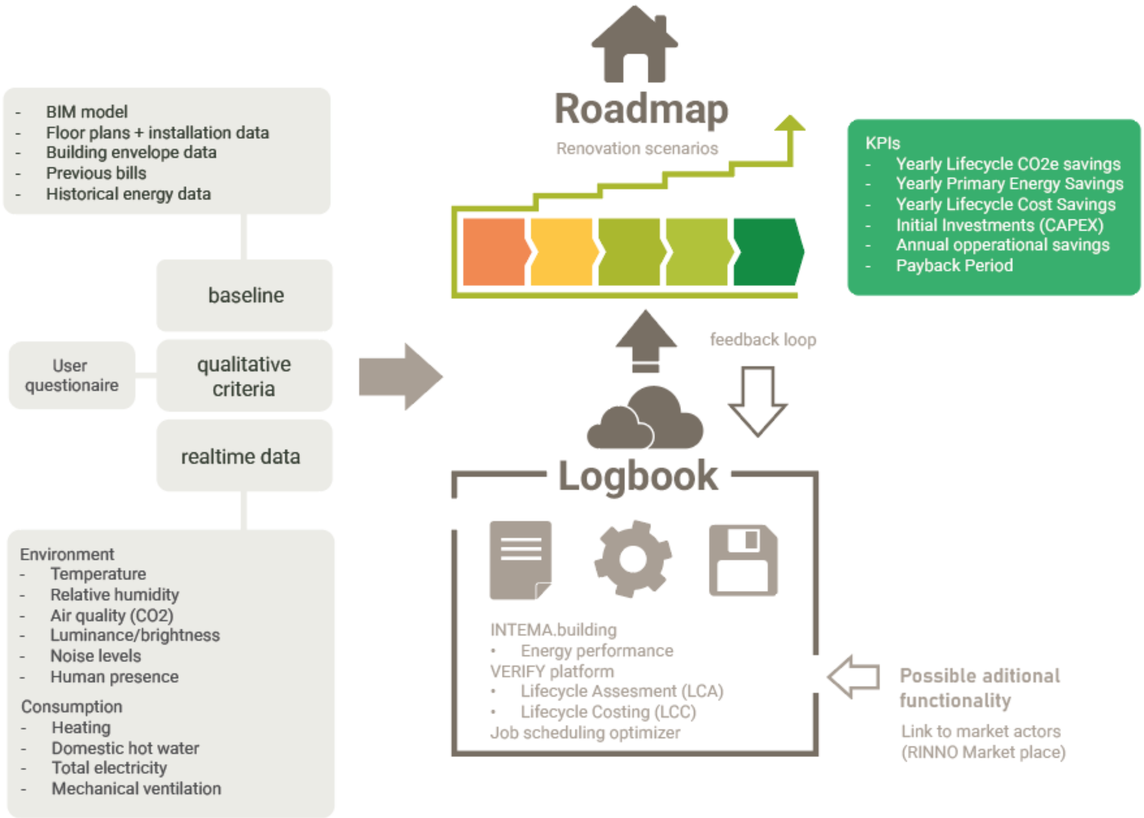

Figure 24. Overview of the RINNO Building Renovation Passport

For each demo building a Building Renovation Passport have been created, consisting of a renovation roadmap and a building logbook. The digital logbook of the building includes static data for the building such as the BIM file and data collected on key building parameters as well as Dynamic data, i.e. Monitored data from the IoT sensors regarding energy consumption and environmental conditions to facilitate dashboarding functionalities.

Starting from capturing the existing condition of the building, an extensive mapping of the building was conducted, which also included 3D scanning and the development of the BIM model. During the renovation specific milestones of the process are recorded in the logbook for the user to have an up-to-date view of the building condition. In addition, the RINNO Renovation Optimiser and Planner supports renovation in stages and provides a roadmap to facilitate deep renovation.

The development of the RINNO Building Renovation Passport scheme have involved significant infrastructure deployment such as IoT monitoring sensors and interoperable IT tools that communicate with each other to support multicriteria performance assessment and propose staged renovation. The tools are described in more detail in chapters 3 and 4.

Key challenges

The following key challenges were addressed in development of the RINNO BRP:

Software interoperability l

Interoperability of different IT tools which need to communicate with each other for the seamless exchange of information. Significant efforts were made to connect various diverse software tools, with specific requirements unique to each tool. This was possible due to the interoperable nature of the software the majority of which were based on open-source tools/code. The use of commercial software poses limitations for the interoperability of the process. Therefore, it is advised to consider open-source code in the development of software tools and platforms to facilitate the wider engagement of the end-users in the BRP concept.

Platform specific or protocol agnostic sensors

The RINNO Platform has been designed to integrate data from **platform-specific** as well as **protocol-agnostic sensors**, ensuring flexibility and interoperability within the ecosystem. This approach supports seamless communication of real-time data, enabling efficient building monitoring and renovation workflows.

IoT Sensor Interoperability

The interoperability of IoT sensors is achieved by adopting widely used **open-source communication protocols**, with MQTT (Message Queuing Telemetry Transport) serving as a cornerstone. MQTT's lightweight, publish-subscribe messaging model ensures low-latency and reliable data exchange, making it ideal for real-time building monitoring applications. Other protocols, such as HTTP/RESTful APIs, may also be integrated depending on the requirements of specific sensors or platforms.

This open architecture allows for compatibility with a wide range of IoT devices, whether they are off-the-shelf commercial sensors or custom-built components. Sensor data is ingested into the RINNO Platform via standardized data formats such as JSON or XML, which facilitates parsing and integration within the platform's centralized data hub.

Connection with Commercial Market Platforms

In addition to supporting open protocols, the RINNO Platform has been developed to connect with **commercial market platforms** for data retrieval. A notable example is the Danish pilot project, where monitoring data was sourced from the **IC Meter platform**. While such integrations are technically feasible, they often require additional effort, including:

Vendor-Specific APIs

Leveraging vendor-specific APIs to query and retrieve data, which may require custom middleware development.

Licensing Constraints

Securing appropriate licensing agreements from vendors, as not all commercial platforms allow unrestricted data access.

Data Format Adaptation

Transforming proprietary data formats into standardized formats compatible with the RINNO Platform.

These factors may introduce additional complexity and costs, particularly when dealing with closed ecosystems or proprietary protocols that restrict third-party access.

Building Monitoring System

The **Building Monitoring System (BMS)** integrates data from IoT sensors to provide real-time insights into building performance, including energy consumption, environmental conditions, and system health. The system relies on the protocols and data aggregation methods to ensure scalability and reliability. It leverages edge computing techniques to preprocess data locally, reducing latency and minimizing bandwidth requirements for transmitting large datasets to the RINNO Platform.

5.2. Guidelines and consultancy for decision making bodies

Building Renovation Passports are considered a promising instrument in addressing many of the barriers associated with building renovation. As such it is expected to have a pivotal role in achieving the increased renovation rates required for the EU to reach its climate targets for 2050. For this reason, the revised Energy Performance of Buildings Directive mandates that all member states should setup a framework for BRPs by 29 May 2026 and determined the general framework for BRPs in Article 12 and Annex III. However, BRPs are still a voluntary instrument unless member states decide to make it mandatory. The EPBD provides clear guidance regarding the content of BRPs to Member States by setting mandatory as well as optional requirements that a BRP scheme should meet. This highlights the importance of BRPs in EU's renovation strategy and promotes their widespread use and standardization.

Member states will need to establish a Building Renovation Passport scheme according to the requirements set in the revised EPBD 1275/2024. Moreover, they will need to ensure cost-effectiveness as BRPs should not 'create a disproportionate burden' to the user.

For this reason, Member States are encouraged to:

1. *Benefit from the links and similarities between EPCs and BRPs to avoid duplication in the data collection process. BRPs are often seen as extension to existing EPC schemes, therefore there needs to be an alignment between the data used for the EPC and those for the renovation roadmap of the BRP.*
2. *Introduce standardized methodologies and processes for the data collection and the development of the EPCs and the renovation roadmaps.*
3. *To avoid excessive costs, certified energy auditors who are responsible for the EPCs should also be responsible for the development of the BRPs. Relevant training courses should be introduced*

in the Member States to ensure quality of data in the produced BRPs.

4. *Implement BRPs in pilot cases which can be used as exemplary projects for successful demonstration and dissemination of the benefits whilst also used for lessons learnt prior to their wider roll-out.*
5. *Ensure data privacy according to the relevant EU and national legislation. Any building and occupant related data need to be handled according to provisions of the GDPR as well as any national methodology which may pose additional restrictions.*
6. *Establish clear access rights to data. BRPs are dynamic instruments and follow the building during various stages throughout their lifecycle. As such, several stakeholders are involved in the development of the Renovation Roadmap and the Building Logbook (building owners, occupants, regulation authorities, contractors etc.). It needs to be ensured that the various stakeholders have access to only that data necessary for their work whilst any data communicated between the various stakeholders remain confidential.*

At the same time European Commission should support the Member States in developing the Building Renovation Passport schemes:

1. *Promote harmonized data standards and formats to ensure interoperability and data exchange between BRPs of different Member States*
2. *Provide guidance, central coordination, and resources to ensure comparability between the various national BRPs. To this end, an EU-wide platform where experiences, lessons learned, and best practices are shared will be useful.*

In addition, the European Commission and Member States should set the framework for the development of financing mechanisms for the implementation of staged renovation projects on a wide scale. To this end, they should encourage and collaborate with financial institutions to develop financing products suitable for the BRP scheme with preferable provisions and terms to enable the uptake of staged renovations.

Logbook, monitoring data and knowledge of the building would make sense in the context of EPC to give a more solid overview of the building state and performance.

As such, building authorities and licensing/governing bodies may benefit from the development of a national/regional Building Renovation Passport scheme. Some general guidelines on the development of such scheme include:

1. *Development of a relevant platform where all data will be stored will require infrastructure with significant storage capacity.*
2. *The Platform should be device and protocol agnostic to enable interoperability with a wide range of IoT monitoring sensors. The roll out of smart meters needs to be considered and the specifications of the equipment installed needs to be considered in the platform development to utilise the data provided.*
3. *The building users will need to be trained on how the platform is used and what are the benefits when participating in the scheme. They will need to be informed on the importance of the monitoring data and the monitoring sensors to avoid:*
   - *Lack of participation due to scepticism and*

- *missing monitoring data due to unplugging the devices.*

4. *Apart from devices, the platform should also be interoperable with the relevant software tools used by building professionals. Either new design tools will need to be developed or additional efforts and arrangements with vendors of commercial software need to be made to allow interoperability of the platform with these software tools. These tools will need to be user-friendly to facilitate the users*

Linking EPCs with BRPs will also require the advancement of the relevant certification tools (to provide energy calculations for the different sets of measures) or development of new software as per the comment above.

5.3. Technical advisory for building professionals and end-users

Building professionals play a crucial role in the successful roll-out of the existing and forthcoming BRP schemes. They will need to communicate to their clients the concept and benefits of BRPs for the public to familiarize and trust the scheme. Delivery of high-quality projects will ensure successful uptake, whilst poor execution will lead to low adoption rates.

Building professionals will carry out the basic steps required for the delivery of the renovation roadmap and logbook, namely:

1. *Energy audits for collecting data on the building's materials and systems, energy consumption patterns to assess its energy performance prior to the renovation.*
2. *Collecting and reviewing any documents of the building (such as drawings, certificates, previous studies, etc.)*
3. *Delivering based on the above data the renovation roadmap which sets out the long-term renovation path in stages proposing the necessary measures to significantly reduce the energy consumption and emissions of the building, in stages, considering also cost-effectiveness of these measures and potential lock-in effects.*
4. *Updating the logbook to include the actions undertaken during each renovation step*

The use of BIM has the potential to improve the accuracy of calculations, minimizing the human error parameter, thereby increasing the quality of BRPs.

Setting a clear strategy for installing IoT systems for the monitoring of the building's energy performance. Such a strategy should:

1. *Determine the metrics required for the analysis to identify the types of monitoring sensors that will be required to be installed,*
2. *Identify secure installation sites for the sensors, and*
3. *Determine contingency plans for missing or defective sensors.*

The IoT system Manager will also need to perform regular maintenance checks to ensure consistency of data and replacing faulty sensors. Backup data collection methods to mitigate physical interference or theft of sensors need to be set-up to minimize loss of monitoring data. By addressing these challenges, future projects can optimize the use of IoT sensors for building renovations, ensuring accurate monitoring, tenant satisfaction, and overall project success.

End-users

The end-users (building owners, occupants) may significantly benefit from adopting a BRP on their property. Therefore, they should actively engage with the scheme and seek advisory from the relevant building professionals. The renovation process laid out at the renovation roadmap provides a cost-effective solution for achieving significant reduction of the building's energy consumption and therefore cost savings. For the BRP approach to be successful the end-users should:

1. *Educate themselves on the benefits of the BRP scheme and implement the renovation actions included in the renovation roadmap to gradually achieve the deep energy renovation of the building.*
2. *Actively engage with the IoT monitoring system and ensure that the sensors are not moved or otherwise compromised (disconnected, broken, etc.). The end-users have a key role in ensuring the successful operation of the monitoring system which is the cornerstone of the building's performance dashboard.*

Information provided by the performance dashboard is essential for assessing the energy performance of the building and for increasing the environmental awareness of the occupants. Through this awareness additional energy savings may be achieved as the public will be able to evaluate the environmental impact of the building's use patterns and adjust to eco-friendlier lifestyle (thermostat adjustments etc.). Therefore, end-users should actively engage with the digital tools regarding monitoring the building's operational conditions.

Securing sensor data

Smart meters for energy consumption needed to get easy access to monitoring data.

Early Planning:

Develop a detailed sensor deployment strategy covering all required metrics, secure installation sites, and contingency plans for missing or defective sensors.

Tenant Engagement:

Engage tenants early with transparent communication about sensors' purposes, addressing privacy concerns proactively.

Secure and Redundant Systems:

Use tamper-proof designs and backup data collection methods to mitigate physical interference or theft.

Continuous Maintenance:

Implement regular checks through the project's solution provided for troubleshooting and replacing faulty sensors.

6. Conclusions

Building Renovation Passports (BRPs) offer significant potential to improve the building energy renovation sector by enhancing the accuracy, efficiency, and effectiveness of renovation planning and execution. By integrating real-time monitoring data and comprehensive building documentation, BRPs enable near real-time assessment of energy performance and provide reliable insights into the actual condition of a building. This facilitates well-informed decision-making for long-term renovation strategies.

Incorporating a building logbook, real-time monitoring, and the current building condition into the Energy Performance Certificate (EPC) framework represents a major improvement in informed decision making on renovation measures. An enriched EPC provides a dynamic and holistic representation of a building's energy usage, historical upgrades, and current operational status, offering greater transparency and empowering stakeholders to make data-driven decisions.

BRPs deliver benefits to both building users and renovation professionals. For occupants, the structured Renovation Roadmap promotes staged renovation efforts focused on maximizing energy savings, thereby increasing renovation uptake. Access to real-time data helps users clearly understand the financial and environmental benefits of energy efficiency measures. For professionals, BRPs offer a reliable, detailed understanding of building characteristics, reducing uncertainties, and improving the precision and confidence of renovation designs.

To ensure successful adoption of BRPs, building occupants must be encouraged to engage actively with the platform, safeguard monitoring equipment, and apply operational recommendations to improve energy performance. Simultaneously, professionals involved in the planning and design stages—such as architects and energy consultants—should embrace the use of BRP platforms, recognizing the long-term efficiencies they offer despite potential upfront investments.

The necessary infrastructure and digital tools are in place. Adoption of the BRP methodology promises not only time savings and streamlined processes in future projects, but also higher renovation quality and stronger alignment with energy and sustainability objectives.

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ABOUT RINNO

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

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

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