



**Building Performance Digitalisation
and Dynamic Logbooks
for Future Value-Driven Services**

Deliverable D4.4

**Title: CHRONICLE tool suite for WLC
assessment and climate neutral building
renovation planning: 2nd revision**



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Table of Abbreviations

Abbreviation	Description
AECO	Architecture, Engineering, Construction, and Operation.
API	Application Programming Interface
BIM	Building Information Modelling
BoM	Bill of Materials
BoM	Bill of Quantities
BRP	Building Renovation Passport
CDE	Common Data Environment
DT	Digital Twin
DHW	Domestic Hot Water
EPD	Environmental Product Declaration
EPS	Expanded Polystyrene
FM	Facility Manager
GWP	Global Warming Potential
H2020	Horizon 2020
HVAC	Heating, Ventilation and Air Conditioning
IA	Investment Appraiser
I/O	Input/Output
KPI	Key Performance Indicator
LCA	Life-Cycle Assessment
LCC	Life-Cycle Costing
MVP	Minimum Valuable Product
PIR	Polyisocyanurate
PUR	Polyurethane

PV	Photovoltaic
PVC	Polyvinyl Chloride
RES	Renewable Energy Sources
ROI	Return on Investment
RP	Renovation Planner
UI	User Interface
WLC	Whole Life-Cycle Carbon
WP	Work Package
XPS	Extruded Polystyrene

Executive summary

The deliverable D4.4 focusses on developing a comprehensive tool suite for Whole Life Carbon (WLC) assessment and climate-neutral building renovation planning. D4.4, is the second revision focusing on enhancing the functionalities and methodologies to provide robust tools that support sustainable renovation practices and contribute to the EU's climate goals.

The **Renovation Planner** is designed to facilitate the planning and execution of building renovations with a focus on sustainability and carbon neutrality.

The MVP of the Renovation Planner has been refined, with detailed architecture, main and subcomponents, and their interactions.

The methodology includes a comprehensive Renovation Measures Catalogue and a Renovation Scenarios Generator to assist in identifying and planning effective renovation strategies that align with sustainability goals.

The technology stack and tools used for implementation are detailed, ensuring a solid technological foundation. It includes information on input/output parameters and API documentation to facilitate integration with other systems.

The **Investment Appraiser** component evaluates the financial and environmental viability of renovation projects, ensuring that investments align with sustainability goals.

The MVP of the Investment Appraiser is described, including its architecture and subcomponents, main features and functionalities.

The methodology includes tools for Lifecycle Cost Estimation, Whole Life Carbon Estimation, and Carbon Cost Benchmark Balance Assessment, aiding assessment of the economic and environmental impact of renovation projects.

The technology stack, implementation, and API documentation are included, providing a clear understanding of how the Investment Appraiser is built and integrated.

The document outlines the **integration and testing** processes for the renovation planner and investment appraiser with details on the testing methodologies used to validate the tools and their functionalities.

A walkthrough of the ChroViewRen UI (interface for both Renovation planner and Investment Appraiser) is provided, covering various aspects such as user registration, login screens, project screens, renovation scenarios, finalization, and the building renovation plan. This section ensures that users can navigate and utilize the tool suite effectively.

1. Introduction

In this deliverable, the Minimum Valuable Product versions of two major tools developed within the CHRONICLE project are presented, namely the Renovation Planner and the Investment Appraiser. Both were already described at a lower level of detail in the first version of this deliverable, D4.3, acknowledging that their development was not yet complete. Consequently, in this document the major and defined updates are provided.

As a reminder, the **Renovation Planner** is an application designed for end-users that provides a customized long-term renovation roadmap tailored to a specific building. It considers the unique characteristics of the building and how these may change over its lifetime. Furthermore, the generated renovation plans are evaluated based on specific KPIs and the user may select their preferred plan based on the KPIs that are of greater significance to them. Finally, the Renovation Planner provides a complete Building Renovation Passport including the generated and selected renovation roadmap along with other relevant information like maintenance details, contractor details and public and/or private renovation grants.

Additionally, the **Investment Appraiser** is a tool designed to evaluate different cost KPIs including Life Cycle Cost, Whole Life Carbon, return on investment (ROI) of renovation projects among others. It provides a comprehensive analysis of the costs and benefits associated with a project, helping users make informed investment decisions.

Both tools are interconnected and work in synergy with other tasks within the CHRONICLE project. They contribute to the overall goal of improving the efficiency and effectiveness of renovation and investment projects.

The Renovation Planner and the Investment Appraiser have been defined at the higher level in task *T2.1 Stakeholders' Requirements, CHRONICLE Framework Specifications & Architecture design (Architecture and Specifications)*, while the Investment Appraiser is also defined in *T2.4 Building Lifecycle Investment Analysis Methodological Framework*, and this has been reflected in the respective deliverables *D2.1 CHRONICLE Business requirements, Use cases & System architecture* and *D2.2 CHRONICLE dynamic Level(s) approach for building and LC performance assessment*. Moreover, the components will be tested regarding their technical specification and impact through the various activities of WP5. In addition to that, the data flows of both tools are reported within D2.1, while the integration information, including data exchanged and APIs, with all related CHRONICLE tools and systems have been defined through the different tasks of WP3. Finally, the fine tuning of the technical specifications and the major development work of the two tools takes place in tasks T4.3 and T4.4.

The current deliverable is structured in the following Sections:

- **Section 1** provides the purpose of the deliverable and its interrelations with the various activities and Work Packages of the project.
- **Section 2** provides updates and the in-depth description of the MVP version of the Renovation Planner tool, including its overview and complete architecture, the methodological approach behind its design and development, the technology stack and implementation tools used, its definitive input and output parameters, the available interfaces and API documentation, and its licensing.
- **Section 3** provides all the above for the Investment Appraiser.
- **Section 4** presents updates on the integration testing cases of the two tools.
- **Section 5** provides a complete walkthrough of the developed ChroViewRen, which is the User Interface designed for the Renovation Planner and the Investment Appraiser. This section can also be read and used as a User Manual for the end-users of the ChroViewRen.
- **Section 6** concludes the deliverable.

- **Section 7** presents the Annex 1, which is an updated and simplified version of the Renovation Measures Catalogue.
- **Section 8** provides the references used in the deliverable.

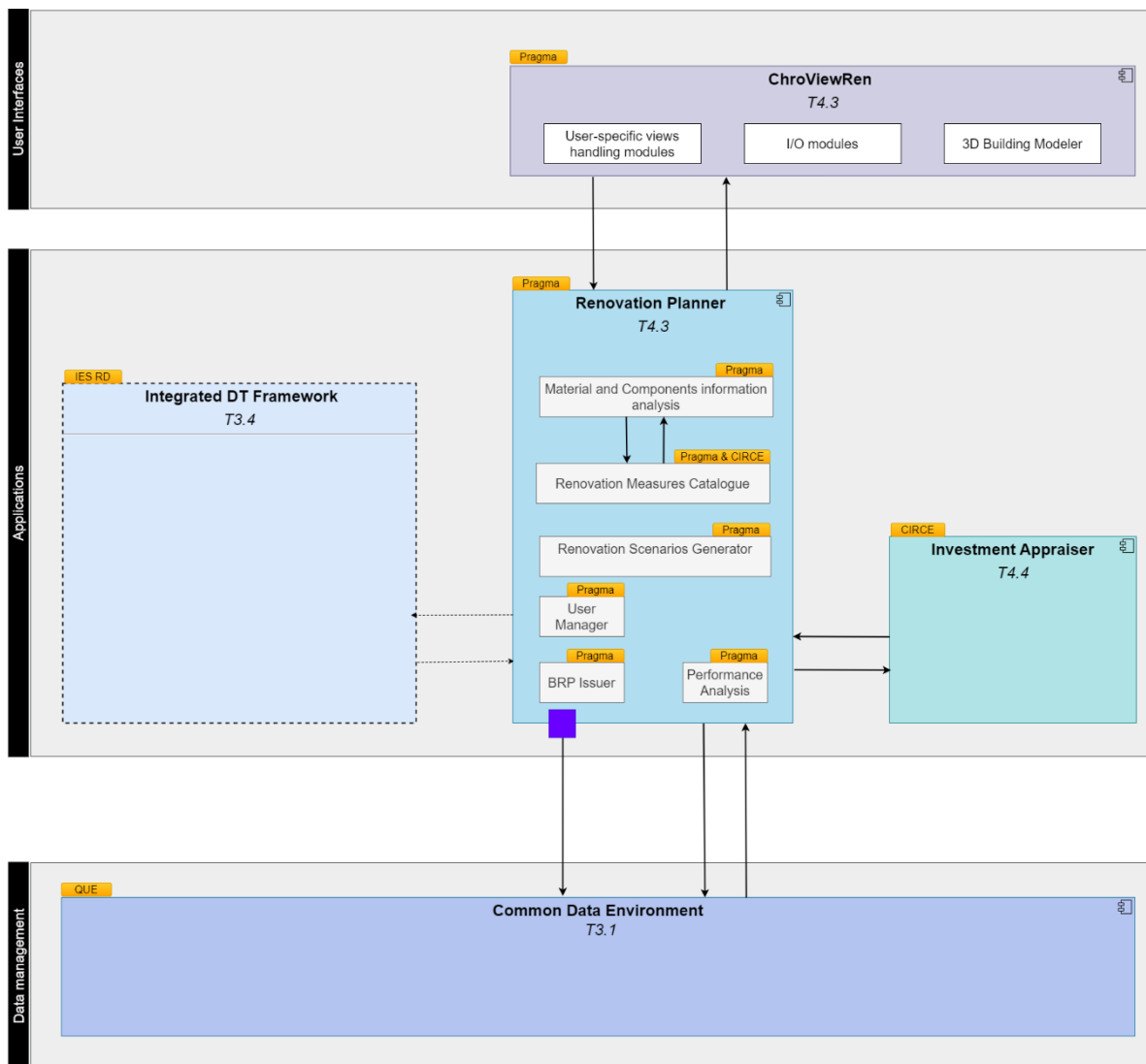
2. Renovation Planner

2.1. Renovation Planner MVP

In this section, the Minimum Valuable Product version of the Renovation Planner will be presented as designed and implemented. As already mentioned above, the focus of this section is to provide updates on the information provided in D4.3 on the Renovation Planner’s architecture along with its sub-components, their methodological approach, the technology stack and implementation tools used, its input and output parameters and its licensing. Additionally, updates are provided on the interfaces implemented between the Renovation Planner and the rest of the CHRONICLE tools that the software is interacting with.

2.2. Renovation Planner Architecture

Figure 1 - Renovation Planner updated architecture



The updated Renovation Planner architecture schema is presented in Figure 1, iterating upon the versions included in deliverables D2.1 and D4.3.

The adopted modular approach confirmed to be well-suited to meet the needs and requirements that came from the synchronous development of the CHRONICLE tools interacting with the Renovation Planner, namely the integrated Digital-Twin framework, the Investment Appraiser and the CDE. As shown in the architectural schema, the Renovation Planner does not function autonomously but in cooperation with those tools. An update to this cooperation is that the previous concept for interfacing between the Renovation Planner and the Integrated DT Framework, and more specifically the Physics-Based Digital-Twin, was taken offline with the operations of this interfacing now conducted before the real-time execution of the Renovation Planner's processes, resulting in the end-user benefiting from the DT's results in quicker, more efficient way.

The sub-components of the Renovation Planner include seven distinct modules that will be described in the next sub-sections, which are *i)* the Renovation Measures Catalogue; *ii)* the Material and Components information analysis component; *iii)* the Renovation Scenarios Generator; *iv)* the Building Renovation Passport (BRP) Issuer; *v)* the Performance Analysis component, *vi)* the User Manager module and *vii)* the ChroViewRen. The ChroViewRen stands as the main UI component for both the Renovation Planner and the Investment Appraiser and contains its own sub-modules, namely *i)* the User-specific views handling module, *ii)* the I/O modules and *iii)* the 3D Building Modeler.

2.2.1. Renovation Planner Subcomponents

This section contains a detailed presentation on the updates of the Renovation Planner's subcomponents, as designed and implemented within T4.3. These subcomponents were first defined and presented in D2.1 and D4.3, and here they are described on a lower level as they have reached their finally defined state.

Renovation Measures Catalogue

The Renovation Measures Catalogue serves as the primary database for the Renovation Planner, which is also accessible by the Investment Appraiser tool. This catalogue is developed using MongoDB and stores all the possible implemented renovation measures. Additionally, the database includes information on all materials and systems used in these measures, along with their properties, such as thermal performance, costs, and maintenance details. Finally, the Renovation Measures Catalogue stores all the simulated scenarios performed by the Physics-Based Digital Twin developed by IES. These simulations are conducted by IES engine for each specific renovation measure, including the associated building materials/systems and provide metrics for the Energy Consumption Overview, Energy Source Breakdown and Carbon Emissions. These outputs are ultimately used by the Investment Appraiser for the calculation of the WLC and Cost KPIs.

The most updated version of the Renovation Measures Catalogue, including the CHRONICLE eligible renovation measures, is presented in Annex 1. The methodology behind selecting those measures for CHRONICLE is explained in sub-section 2.2.1. Regarding the technical and ecological data of the materials and systems, the Renovation Measures Catalogue leveraged the EPD-based data sets provided by One Click LCA (*LCA & EPDs for Construction & Manufacturing | One Click LCA*, n.d.), cross-referenced with ÖKOBAUDAT (Bbsr, n.d.-b), when applicable. Finally, data on the costs of the materials and systems are more difficult to find in open state and localized for all the pilot sites' countries, so feedback on this type of data is gathered from the pilot site leaders and complemented by CIRCE's cost databases. Sources are summarised in Table 1 below.

Table 1: Renovation measures data sources by pilot

Pilot	Source of data
Ireland	Costs obtained from the National Home Energy Upgrade Scheme SEAI-OSS-Median-Costs-and-Grants.pdf
Denmark	Renovation Budget provided by the pilot
Greece	Construction costs provided by the pilot
Spain	Public construction Database https://generadordeprecios.info/
Switzerland	Prices obtained from Association CECB. (2024). <i>Outil CECB v6.4 Manuel utilisateur</i> . CECB Agence romande. Retrieved from CECB website. https://www.cecb.ch/media/manuel_utilisateur_cecb_v6-4.pdf

Material and Components information analysis

The Material and Components Information Analysis component is tasked with mapping each proposed renovation measure in a generated renovation plan to the specific materials and systems needed to complete that measure. The component looks at the baseline structural element that each proposed renovation measure is scheduled to modify and selects the corresponding materials, their quantity and thickness, or systems to be installed/replaced, and creates and provides this mapping as an output. Moreover, this component provides the back-end functionality to enable the end-user to input their own materials and systems' data through the ChroViewRen, whenever their values are missing or in case the user wants to provide more localized data than the ones already provided by the tool. Additionally, through this component the user can also provide new materials (along with their properties) from their own expertise, if those are not already provided by the tool, and associate them with the available renovation measures. The user-specific data are, finally, sent to the Renovation Measures Catalogue database for storage and future use.

Renovation Scenarios Generator

The Renovation Scenarios Generator is the core engine of the Renovation Planner. It calculates and presents combinations of all eligible renovation measures, resulting in various renovation plans. Additionally, it forwards these plans to the Investment Appraiser to obtain the corresponding calculated WLC and Cost KPIs. Further details on the calculations of the generation of the renovation plans are provided in sub-section 2.2.2.

Building Renovation Passport (BRP) Issuer

The Building Renovation Passport Issuer is the sub-component responsible for creating the Building Renovation Passport for a selected renovation plan. The BRP includes and outlines the selected renovation roadmap along with the specific renovation measures, details on the maintenance of the installed components and materials, and any other information considered relevant to the end-user regarding the planned renovation (e.g. required permits, contractors, personalized timeline). The BRP also presents the final KPIs related to the selected renovation plan. Finally, this component enables the BRP to be downloaded by the user as a PDF file and forwards it in JSON format to the CDE.

Performance Analysis

The Performance Analysis component compares and validates the simulated KPIs of the selected renovation plan against the actual post-renovation IoT-measured data. It generates an analysis

report for the user, showing the comparison between the Renovation Planner's forecasted post-renovation building performance and the actual performance, including cost analysis.

User Manager

The User Manager module handles the registration, authorization and authentication of the end-users, assigning them specific user roles, namely the admin, engineer and tenant roles. Based on these roles, the end-users are served different views and functionalities of the Renovation Planner to meet their requirements.

ChroViewRen

The ChroViewRen component is the main user interface of the Renovation Planner. A complete walkthrough of the developed user interface is included in section 5 of this deliverable. ChroViewRen's sub-components include:

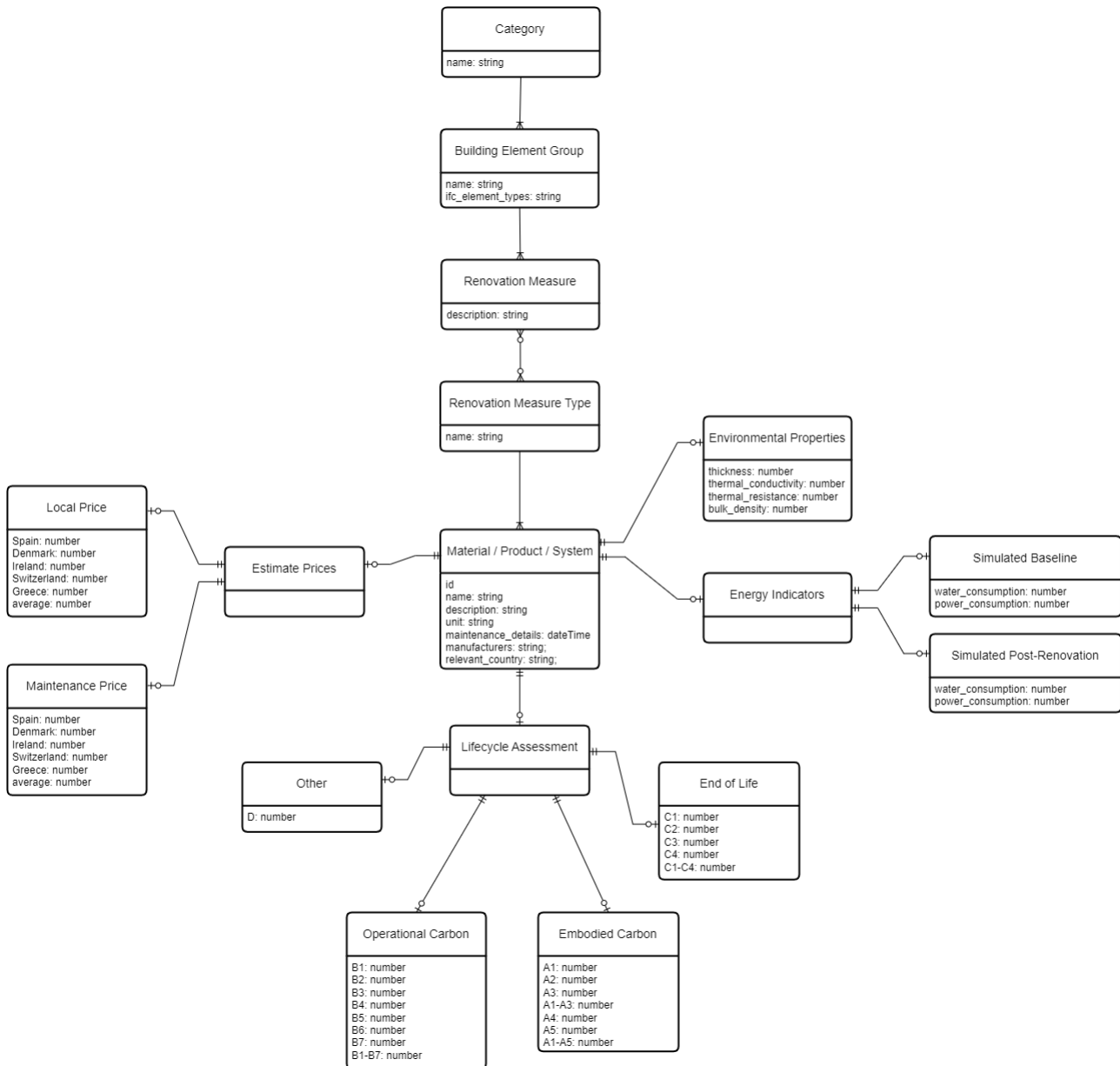
- **the User-specific views handling module:** This module handles the views served to the end-users based on the assigned user-roles and their assigned renovation projects.
- **the I/O modules:** These modules facilitate all the interactive input/output functionalities between the end-users and the Renovation Planner's front-end as the renovation planning process is underway or whenever the end-user wants to provide their own data regarding new or existing materials and systems.
- **the 3D Building Modeler:** The modeler provides the end-user a detailed 3D model of the building related to the project they are working on. It enables them to see exactly which structural and/or system elements they will be modifying through selecting new renovation measures to implement.

2.3. Methodological Approach

This section includes an update to the methodology followed for the development and definition of the Renovation Measures Catalogue and the Renovation Scenarios Generator. These two components are considered as the main engine in the Renovation Planner's backend and so in the following sub-sections updates on the details behind their definition and operation are provided. The descriptions provided for the rest of the subcomponents in the previous section, in addition to those of D2.1 and D4.3, are considered sufficient to make their methodological aspects evident.

2.3.1. Renovation Measures Catalogue

Figure 2 - Renovation Measures Catalogue db schema



In Figure 2, the final scheme of the Renovation Measures Catalogue database is presented. As already mentioned in sub-section 2.1.2 and shown in the figure above, in the developed database the following data are stored:

- **Building Element Group:** Entity that describes the building element groups, namely the walls, roofs, slabs, windows, HVAC and RES systems.
- **Renovation Measure – Renovation Measure Type:** Entities that describe the available renovation measures per building element group.
- **Material / Product / System:** Entity that describes the available products (e.g. materials and systems) stored in the database. Those are associated to specific renovation measures.
- **Estimate Prices:** Entity that provides the estimated local and maintenance prices for each product.
- **(Product) Lifecycle Assessment:** Entity that describes the impact of each product in lifecycle assessment of the building under renovation. As mentioned in sub-section 2.1.2, the

operational carbon data for each product are generated “offline” by the Physics-Based Digital-Twin and are stored in the Renovation Measures Catalogue.

- **Environmental Properties:** Entity that describes the environmental properties of a stored product.
- **Energy Indicators:** Entity that describes the impact of a product to the energy indicators of the building under renovation. The baseline energy indicators refer to the baseline status of the building, while the post-renovation energy indicators refer to the forecasted values that should be valid for the post-renovation status of the building. Both categories of indicators are simulated within the Physics-Based Digital-Twin and are stored in the Renovation Measures Catalogue.

The renovation measure – ifc element mapping mentioned in D4.3 is also completed and described in the Table 2 below.

Table 2 - Renovation measures - IFC elements mapping

Renovation Measure Name	Category	IFC element(s)
Adding or increasing insulation (Wall)	Envelope	IfcWall, IfcWallStandardCase, IfcWallElementedCase
Adding or increasing insulation (Floor)	Envelope	IfcSlab
Adding or increasing insulation (Roof)	Envelope	IfcRoof
Installation of window frame	Fenestration	IfcWindow, IfcWindowStandardCase
Installation of window glass	Fenestration	IfcWindow, IfcWindowStandardCase
Installation/Replacement of a boiler	HVAC	IfcBoiler, IfcBoilerType
Installation/Replacement of electric radiators	HVAC	IfcSpaceHeater, IfcSpaceHeaterType
Installation/Replacement of heat pumps	HVAC	IfcUnitaryEquipment, IfcUnitaryEquipmentType
Installation of photovoltaic panels	RES	IfcSolarDevice, IfcSolarDeviceType

Additionally, the categories of the building material and systems data coming from the databases ÖKOBAUDAT and One-Click LCA were manually defined and mapped. This enabled the creation of a unified classification structure under which all available products per category were stored in the Renovation Measures Catalogue. The classification structure is provided below:

- Heating/Cooling Systems
- Heat Pump
- Ground source (brine-water), vertical

- Water source (water-water), vertical
- Air source (air-air), multisplit
- Air source (air-water), combi (DHW + heating + cooling)
- Heat Resistive
- Electric convector radiator
- Heat Infrared
- Electric radiant infrared panel
- Heat Gas
- Gas Boiler
- Heat Oil
- Oil condensing Boiler
- Heat Biomass
- Pellet (biomass) Boiler
- Energy Generators
- Photovoltaic
- 1m² PV panel, roof
- 1m² Building Integrated PV glass, façade
- Energy Storage
- Battery
- 1kWh Electrical storage, Li-ion
- Insulation
- Expanded Polystyrene (EPS)
- EPS, d 45 [λ 0,033]
- Extruded Polystyrene (XPS)
- XPS insulation board
- Mineral Wool
- Stone wool insulation
- Glass and stone wool insulation
- Rigid foam (PUR) or (PIR) HFC
- PIR insulation panel
- PUR insulation panel
- (PUR) or (PIR) panel, HFC, non-gas-permeable coating
- PIR insulation panel
- Frames
- Metallic
- Metallic, d 2800
- Wood, high density
- Wood, d 700
- PVC (two cavities)
- PVE (two cavities), d 1000
- Glass
- Glazing, double-glazing, normal, (E=0.89)
- Insulating glass unit
- 1 normal glass + 1 low emissivity glass (0.1>E>0.03)
- Insulating glass unit
- Glass, normal, laminar (E=0.89)
- Insulating glass unit

The Renovation Measures Catalogue at its current state stores 46 different products that are categorized based on the classification that was described above. In the near future and as the fine-tuning of the Renovation Planner proceeds, more products will be stored in the database as we have

identified a total of 187 products coming from the ÖKOBAUDAT and One-Click LCA databases. Along with the higher number of products, new renovation measures will be introduced in the tool to accommodate them. The simplified and updated version of the Renovation Measures Catalogue at its current state is included in Annex 1.

2.3.2. Renovation Scenarios Generator

This sub-section describes the formula used to calculate the total number of generated renovation plans where each building element group category (e.g., envelope, fenestration, HVAC, RES) contains specific renovation measures (e.g., Adding or increasing insulation (Wall), Installation/Replacement of a boiler). Each renovation measure is implemented through the application of a product (material or system) to the different building elements of the building element group categories. As a reminder from the information provided in D4.3, it was defined that only one product can be applied through a renovation measure to each structural or system element of the building.

Definitions of the calculation formula elements

1. Renovation Measure Categories (*RMCs*): Envelope, Fenestration, HVAC, RES.
2. Renovation Measures (*RM*s): Specific actions within each RMC.
3. Product (*P*): A renovation measure can consist of a single product (materials or systems).
4. Building Element (*BE*s): Distinct elements where a renovation measure can be applied.

Parameters

- *C*: Number of Renovation Measure Categories (*RMCs*).
- *R_c*: Number of selected Renovation Measures within category *c*.
- *P_{cr}*: Number of selected products for Renovation Measure *r* within category *c*.
- *G_{cr}*: Number of selected building elements where Renovation Measure *r* in category *c* can be applied.

Formula Derivation

1. *Calculate possible selected product combinations for each selected renovation measure:*

For each renovation measure *r* within category *c*, the possible selected product configurations are *P_{cr}*.

2. *Calculate selected building element applications for each selected renovation measure:*

For each selected renovation measure *r* in category *c*, it can be applied to *G_{cr}* different selected building elements.

3. *Calculate possible combinations for each selected renovation measure:*

For each selected renovation measure *r*, combine the selected product and building element possibilities:

$$\text{Total combinations for RM } r = L_{cr} * G_{cr}$$

4. *Calculate the total number of renovation plans across all categories:*

To get the total renovation plans across all categories, sum the selected products and building element possibilities for each renovation measure in each category:

$$\text{Total Renovation Plans} = \prod_{(c=1 \text{ to } C)} \prod_{(r=1 \text{ to } R_c)} (L_{cr} * G_{cr})$$

Final Formula

The formula for calculating the total number of the generated renovation plans is:

$$\text{Total Renovation Plans} = \prod_{(c=1 \text{ to } C)} \prod_{(r=1 \text{ to } R_c)} (L_{cr} * G_{cr})$$

Below follows a calculation example.

Lets supposedly have selected 2 Renovation Measure Categories: Envelope and HVAC.

For the Envelope Category we have selected:

- 2 Renovation Measures: Adding or increasing insulation (Wall) (2 products for 3 building elements (Walls)) and Adding or increasing insulation (Floor) (1 product for 2 building elements (Floors))

For the HVAC Category we have selected:

- 1 Renovation Measure: Installation/Replacement of a boiler (2 products for 1 building element (Boiler))

Using the formula we've described above:

1. For the Envelope:

- Adding or increasing insulation (Wall) = $2 * 3 = 6$
- Adding or increasing insulation (Floor) = $1 * 2 = 2$
- Total scenarios for the Envelope = $6 * 2 = 12$

2. For the HVAC:

- Installation/Replacement of a boiler = $2 * 1 = 2$
- Total scenarios for the HVAC = $2 * 1 = 2$

3. Total Renovation Plans = $12 * 2 = 24$

2.4. Technology stack and Implementation tools

This section lists all the known libraries, tools & packages used by the Renovation Planner for its MVP version. This table was first presented in D4.3 and is updated in this deliverable.

Table 3 - Technologies used in the Renovation Planner

Technology name	Version	License
Angular	15.2.11	MIT
Nebular	11.0.1	MIT
Bootstrap	4.6.2	MIT
Thatopen/components	2.4.3	MIT
Node.js	18.10.0	MIT
Express.js	4.19.2	MIT
Jsonwebtoken	9.0.2	MIT
MongoDB	7.0.8	SSPL (Server Side Public License)
IfcOpenShell	0.7.0	LGPL-3.0
Python	3.11.8	Python Software Foundation License
Nginx	1.24.0	2-clause BSD License

- **Frontend:** The user interface (UI) is built with Angular, a popular JavaScript framework known for its clarity, efficiency, and scalability. Nebular, an Angular UI component library, provides pre-built components and a consistent design language. Bootstrap, a widely used CSS framework, is incorporated to ensure the responsiveness and the consistent behaviour of the UI across different screen sizes.
- **IFC Viewer:** The Renovation Planner incorporates an IFC viewer on the UI which is based on thatopen/components library. This component allows users to visualize and interact with IFC building models directly within the web interface.
- **Authorization / Authentication Service:** A dedicated authorization and authentication service is implemented using Node.js, a JavaScript runtime environment. Express.js, a popular Node.js web framework, is used to simplify the development and organization of the REST API. User authentication and authorization are handled through Jsonwebtoken, a secure token-based authentication mechanism. Finally, MongoDB serves as the service's database for storing user data.
- **Renovation Measures Catalogue database:** The application features a Renovation Measures Catalogue, which stores information about various renovation options in MongoDB. This catalogue is integrated with the existing authorization and authentication service, which manages access control for the renovation measures data in addition to user authentication. The authorization service ensures that all data reading, writing and editing operations related to the Renovation Measures Catalogue are protected, preventing unauthorized access and maintaining data integrity.
- **IFC Handling:** A separate service, developed using Python, handles, parses and modifies IFC files. This service uses the IfcOpenShell library, a powerful open-source toolkit for working with IFC data.

- **Deployment:** The application is deployed using Nginx. Nginx acts as a reverse proxy, efficiently routing requests to the backend services. It also serves the static files for the Angular-based user interface.

2.5. Input/Output parameters

This section contains a detailed list of the required inputs and delivered outputs by the Renovation Planner. The table presents the input and output data related to the Renovation Planner, which tools provide them or require them, and how these data will be communicated between the identified CHRONICLE tools. This list was first documented in D2.1 and updated in D4.3, so in this version, the final updates are provided along with adding the relevant details for each piece of data.

Table 4 - Renovation Planner's I/O data details

I/O Data	#	Description	Received from (input data) / Required by (output data)	Communication details	
				Format	Method
Input Data	Input-1	Baseline .ifc file	CDE	Format	IFC
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Input-2	Project list	CDE	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Input-3	Post-renovation IoT data	CDE	Format	JSON
				Method	GET/POST
				Endpoint	REST APIs
				Protocol	RESTful
	Input-4	Simulated Energy indicators	Integrated DT Framework (Physics-Based Digital Twin)	Format	XLS
				Method	Manual/Offline
				Endpoint	NA
				Protocol	NA
	Input-5	Simulated Comfort KPIs	Integrated DT Framework (Data-Driven Digital Twin)	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Input-6	Simulated WLC KPIs	Investment Appraiser	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
Input-7	Simulated Cost KPIs	Investment Appraiser	Format	JSON	
			Method	GET/POST	
			Endpoint	REST API	
			Protocol	RESTful	
Input-8	Operational Carbon	Integrated DT Framework (Physics-Based Digital Twin)	Format	XLS	
			Method	Manual/Offline	
			Endpoint	NA	
			Protocol	NA	

	Input-9	Carbon Benchmark Balance Assessment	Investment Appraiser	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Input-10	Baseline Energy indicators	Integrated DT Framework (Physics-Based Digital Twin)	Format	XLS
				Method	Manual/Offline
				Endpoint	NA
				Protocol	NA
	Input-11	Carbon Bill	Investment Appraiser	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
Output Data	Output-1	Generated renovation scenarios .json files	Integrated DT Framework (Physics-Based Digital Twin), Investment Appraiser	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Output-2	Selected renovation scenario .ifc file	CDE	Format	IFC
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Output-3	Selected renovation scenario - Energy KPIs	CDE	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Output-4	Selected renovation scenario - Comfort KPIs	CDE	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Output-5	Selected renovation scenario - WLC KPIs	CDE	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Output-6	Selected renovation scenario - Cost KPIs	CDE	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
Output-7	Selected renovation scenario - Building Renovation Passport (BRP)	CDE	Format	JSON	
			Method	GET/POST	
			Endpoint	REST API	
			Protocol	RESTful	
Output-8	Carbon Bill	CDE	Format	JSON	
			Method	GET/POST	
			Endpoint	REST API	
			Protocol	RESTful	
Output-9	Post-renovation analysis	CDE	Format	JSON	
			Method	GET/POST	
			Endpoint	REST API	

				Protocol	RESTful
	Output-10	Baseline .IFC file	Investment Appraiser	Format	IFC
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Output-11	Generated scenarios Energy indicators (energy/water consumption)	Investment Appraiser	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Output-12	Baseline Energy indicators (energy/water consumption)	Investment Appraiser	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful
	Output-13	Operational Carbon	Investment Appraiser	Format	JSON
				Method	GET/POST
				Endpoint	REST API
				Protocol	RESTful

2.6. Interfaces and API documentation

This section provides the updates on the description of the interfaces between the Renovation Planner and the other associated CHRONICLE components. As already mentioned in the previous sections, the Renovation Planner interfaces with the CDE and the Investment Appraiser. It is agreed that all communications and data exchanges taking place between the Renovation Planner and the aforementioned CHRONICLE tools will happen through established APIs. Additionally, as already mentioned in sub-section 2.2, the previously documented communication between the Renovation Planner and the Physics-Based Digital-Twin was re-designed and developed to work in an “offline” manner to provide and use the Digital Twin’s simulation results immediately and, thus, avoiding any probable lagging simulation time that could hinder the user’s experience with the ChroViewRen.

More specifically, as of its MVP state the Renovation Planner tool leverages the endpoints developed by QUE for the CDE’s API, which are documented in D3.1 and the endpoints developed by CIRCE for the Investment Appraiser’s API, which are documented in sub-section 3.5. Within the implementation of the Renovation Planner, the REST API service that is developed for user authentication and authorization exposes endpoints that the frontend application utilizes for login, registration, and access control, which were documented in D4.3.

2.7. Licensing

- **Nature of the Code:** Closed-source. Renovation Planner's source code is confidential and maintained internally by the development team within a secure environment.
- **Delivery Form:** Deployed on a Virtual Machine (VM) with Nginx. The application is deployed on a virtual machine using Nginx as a reverse proxy and web server. Users access the Renovation Planner through a web browser.
- **Source Code Repository:** Private GitLab repository. The source code is version-controlled using a private GitLab repository to facilitate development workflows and secure deployment processes. Access to this repository is restricted to authorized team members.
- **Component License:** The web application itself, being closed-source, does not have an open-source license. However, it uses various open-source components, each with its respective licenses, as detailed in Table 2. The licenses for these components include MIT, SSPL, LGPL-3.0, 2-clause BSD License and the Python Software Foundation License.

3. Investment Appraiser

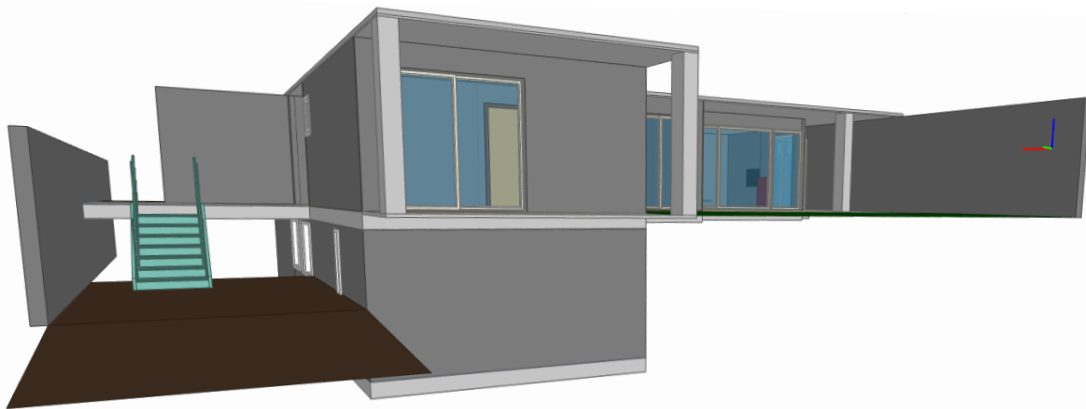
3.1. Investment Appraiser MVP

The Investment Appraiser has been developed as a decision-support tool to assess the cost effectiveness and feasibility of different energy efficiency measures applied to buildings. It integrates various data sources and methodologies to evaluate potential investment scenarios, providing results that align with the validation methodology of the CHRONICLE project.

To validate the tool, HYPERTECH'S TESTBED model has been selected. This model represents a residential building for which an IFC file has been provided.

For the analysis, only specific floors have been considered, based on availability of the necessary information regarding materials and wall stratification.(Figure 3- Hypertech Testbed 3D model).

Figure 3 - Hypertech Testbed 3D model



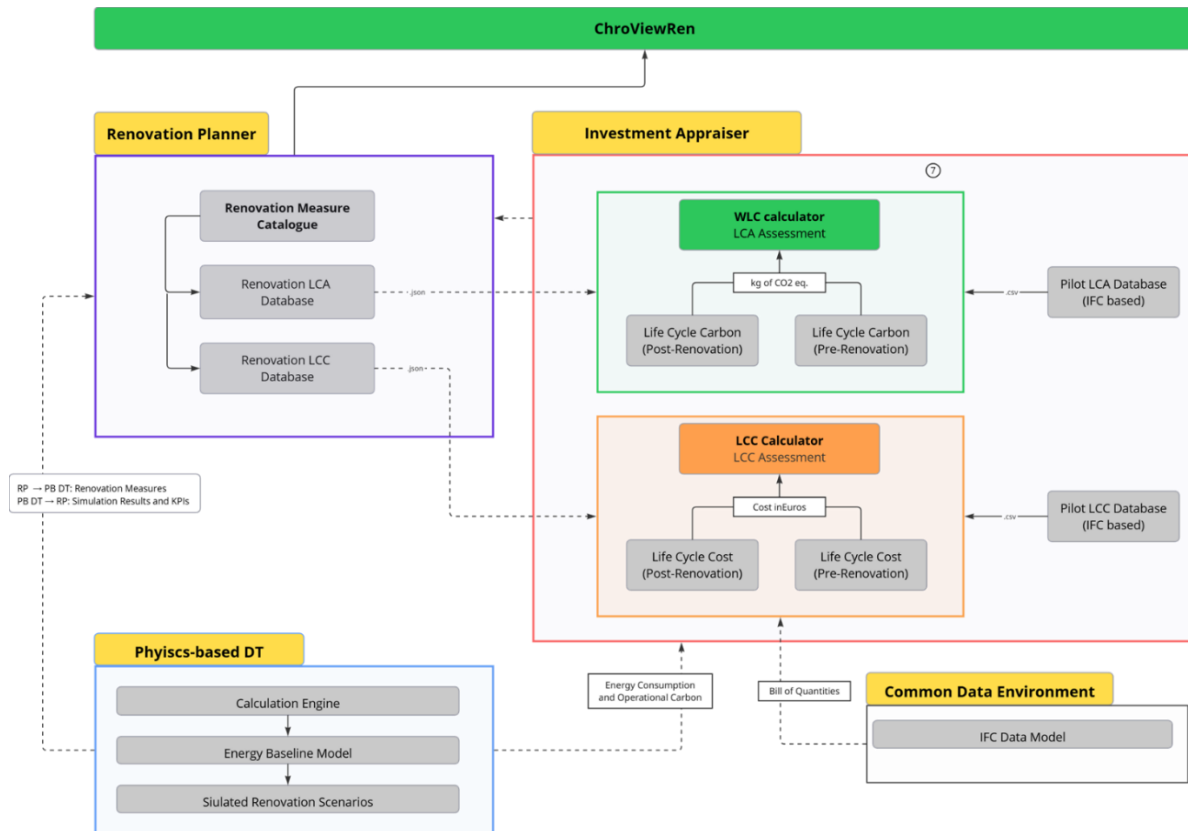
The structural framework can be defined as a reinforced concrete grid of pillars and concrete slabs. The foundation system also utilizes reinforced concrete.

The Bill of Materials (BoM) and Bill of Quantities (BoQ) have been extracted from the following building elements and used to feed the Investment Appraiser tool: External Walls, Roofing, Fenestration, External doors, Wall Finishes, Flooring, Ceilings and HVAC systems.

Due to the sensitive nature of the building's information and the public accessibility of this deliverable, specific material details have been omitted. However, the omitted information has been used internally for the necessary calculations within the Investment Appraiser tool.

3.1.1. Investment Appraiser Architecture

Figure 4 - Life Cycle Cost and Whole Life Carbon Subcomponents



The diagram illustrates the workflow of the ChroViewRen. It shows the interaction between the Renovation Planner, Investment Appraiser, and PB DT, highlighting the flow of information related to energy consumption, operational carbon, renovation measures, simulation results, and KPIs.

For calculating the WLC and LCC KPIs a baseline building per pilot and for the HYPERTECH Testbed has been defined. A baseline of a building, in terms of carbon measurement and life cycle cost, is a fixed reference point based on data obtained from the Building Information Model (BIM). This baseline includes the main construction components of each pilot project and the associated information on costs and equivalent CO₂ emissions. This data is embedded in a JSON file that is part of the Investment Appraiser code.

The baseline serves as a foundation to which the user can add various renovation plans. By doing so, the total carbon footprint and life cycle cost can be calculated, incorporating both the baseline and the chosen renovations. This approach helps in assessing the environmental and financial impact of different renovation strategies over the building's life cycle.

Table 5 - Investment Appraiser input data

Input	IA Sub component	Format	Source component	Responsible Partner per source component
Baseline Bill of quantities for LCA	Whole Life Carbon	IFC to be parceled via Open Shell Plugin, alternatively a CSV will be created using BIM software	CDE	QUE
Operational Carbon Renovated		CSV	PB DT	IES
Operational Carbon Baseline		CSV	PB DT	IES
LCA DATA of Selected renovation measures		JSON	RENOVATION PLANNER	PRAGMA&CIRCE
Baseline Bill of quantities for LCC	Life Cycle Cost	IFC to be parceled via Open Shell Plugin, alternatively a CSV will be created using BIM software	CDE	QUE
Operational Cost Renovated		CSV	PB DT	IES
Operational Cost Baseline		CSV	PB DT	IES
LCC DATA of Selected renovation measures		JSON	RENOVATION PLANNER	PRAGMA&CIRCE

Table 6 - Investment Appraiser output data

Output	IA Subcomponent	Format	Destination component	Responsible Partner UI
Whole Life Carbon	Whole Life Carbon Calculator	JSON (Number: X.XXX,XX Kg of CO2 eq)	ChroView Ren	PRAGMA
Life Cycle Cost	Life Cycle Cost Estimator	JSON (Total € X.XXX,XX €)	ChroView Ren	PRAGMA

3.2. Subcomponents & Methodological Approach

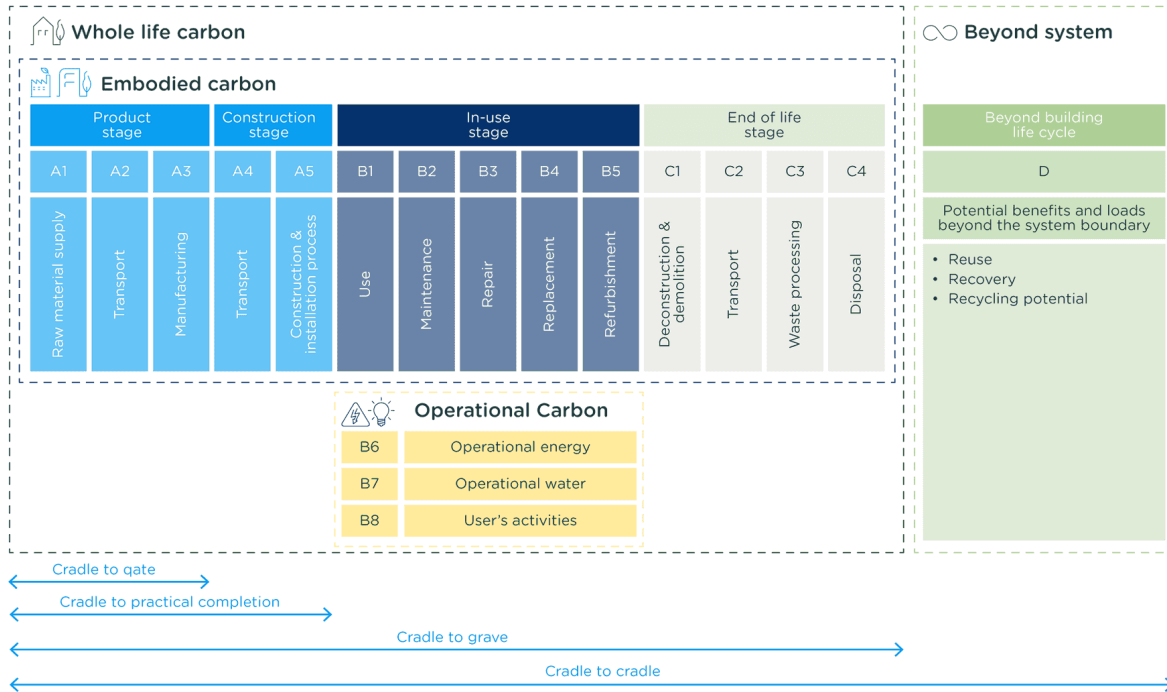
3.2.1. Lifecycle Cost Estimator

Table 7 - Investment Appraiser generated KPIs

KPI ID	KPI Name	Formula	Unit
1	Building Materials Cost A1-A5	Total Cost (EUR)= \sum (Quantity of Material (kg)×Price per Quantity of Material (EUR/kg))	EUR
2	Yearly Energy Consumption Cost B6	(Baseline energy consumption × updated yearly energy price) + (Renovated energy consumption × updated yearly energy price)	EUR/year
3	Yearly Maintenance Cost	Yearly maintenance ratio cost × total built surface (sqm)	EUR/year
4	Carbon Bill	Yearly Carbon Cost X WLC	EUR
5	Total Cost LCC	Carbon bill+ Maintenance cost+ Water Consumption Cost+ Energy Consumption Cost + Building Mateial Costs	EUR
6	WLC Cost Performance	$CCBBA = \frac{LCC(Baseline + Renovation Plan)}{LCA (Basline + Renovation Plan)}$	Ratio
7	Return of Investment	ROI(%)=(Total Refurbishment Cost - Net Gain from Refurbishment)×100	%
8	Payback Period	Payback Period = Annual Net Income or Savings - Total Refurbishment Cost	Years

3.2.2. Whole Life Carbon Estimator

Figure 5 - Building lifecycle stages used to define a system boundary. Reproduced from EN 15978:2011 with B8 module added. <https://www.ramboll.com/insights/decarbonise-for-net-zero/which-life-cycle-assessment>



Life cycle stage modelling

The modelling of life cycle stages is based on modules as defined in EN 15978: the product stage (A1-A5), the use stage (B1-B6), the end-of-life stage (C1-C4), benefits and loads beyond the system boundary (D). Ideally, the scope should reflect the cradle-to-grave life span.

Mass and energy balance

All material and energy flows (inputs and outputs) should be considered, where possible. For certain flows, cut-off criteria according to EN 15978 or EN 15804 may be applied.

All materials used, such as concrete, steel, wood, glass, or insulation, should be quantified. Also, ancillary materials such as paints, adhesives or other auxiliary substances. It is also essential to include details of the recycled content and other relevant circularity indicators in the report. Material outputs include waste generated and losses (e.g. damaged products) during the lifecycle.

Energy inputs should be reported including the energy consumed during the building's lifecycle. During the design phase, the energy use may be modelled based on available information for heating, cooling, ventilation, and lighting based on the building design. During the operational phase, data may be obtained from electricity and gas bills, and from sensors and meters. On-site generation should be reporting energy use in the building and exported energy separately. It includes photovoltaic panels, solar thermal collectors, biomass stoves or geothermal heat pumps.

$$WLC-GWP = GWP_{A1-A3} + GWP_{A4} + GWP_{A5} + GWP_{B1-B5} + GWP_{B6} + GWP_{C1-C4} + GWP_D$$

3.2.3. Carbon Cost Benchmark Balance Assessment

The CCBBA subcomponent has not changed since the last deliverable. It will be obtained by summing the total carbon emissions of the baseline and the selected renovation plan on one side, and on the other side, the total life cycle cost of the baseline and the same assigned renovation plan. Finally, the cost will be divided by the carbon to obtain the result in €/Kg CO₂ eq.

$$CCBBA = \frac{LCC(Baseline + Renovation Plan)}{LCA (Basline + Renovation Plan)}$$

Life Cycle Cost: The total cost of a building over its entire lifespan, including initial costs, operation, maintenance, and disposal costs.

Life Cycle Analysis; A systematic process to evaluate the environmental impacts of a building throughout its entire life cycle, from raw material extraction to disposal. Only GWP is considered for the tool

Baseline A reference point or standard against which changes in performance or progress can be measured in the building

Renovation Plan A detailed proposal for updating and improving an existing building to enhance its performance, efficiency, and sustainability. The renovation plans are based on the measures detailed in the renovation catalogue, [Annex 1](#)

3.3. Technology stack and Implementation tools

Table 8 - Technologies used in the Investment Appraiser

Technology name	Version	License
Python	3.10.0	Python Software Foundation License
Pandas	2.0.3	BSD 3-Clause License
IFCOpenShell	0.7.0	LGPL-3.0

3.4. Input/Output parameters

Table 9 – Input data for LCA LCC

ID	KPI Name	LCA (Kg CO2 Eq.)	LCC (€)	Input source
A1	Raw Material Supply	Bill of Quantities × Embodied emission factor	Bill of Quantities × Construction material costs	Baseline BIM Model
A2	Transport	Material Quantity × Transport emission factor	Material Quantity × Transport cost per km/ton	Transport log, distance matrix
A3	Manufacturing	Emission factor per unit product	Manufacturing cost per unit product	Manufacturer EPD, product database
A1–A3	Product Stage	Sum of A1 to A3	Sum of A1 to A3	Derived from A1–A3

A4	Transport to site	Load × Distance × Transport mode emission factor	Load × Distance × Cost per mode	Logistics plan, Transport specs
A5	Construction & Installation Process	Machinery usage × Fuel emission factor	Labor + Equipment rental + Installation costs	Site plan, equipment specs
A1–A5	Construction Stage	Sum of A1 to A5	Sum of A1 to A5	Derived from A1–A5
B1–B2	Use and Maintenance	Estimated based on operation profile	Annual O&M cost × Ratio €/sqm	Digital Twin, JSON (Ratio €/sqm)
B4	Repair	Emissions from replacement materials	Cost of materials + Labor	Renovation Planner
B5	Replacement	Emissions from recurring replacements	Lifecycle replacement cost	Renovation Planner, Material lifecycle data
B6	Operational Energy	Energy usage × CO2 factor	Energy consumption × tariff	Digital Twin, Energy simulation
B1–B7	Use Stage	Sum of B1 to B7	Sum of B1 to B7	Pilot LCA LCC database
C1	Deconstruction & Demolition	Equipment usage × Emission factor	Demolition cost	Demolition plan, Equipment specs
C2	Transport	Waste × Distance × Mode emission factor	Waste × Distance × Cost per mode	Waste transport records
C3	Waste Processing	Waste processing emissions per kg	Waste processing cost per kg	Waste management provider data
C4	Disposal	Landfill/incineration emission factors	Disposal fees per unit	Disposal regulations, provider data
C1–C4	Disposal Stage	Sum of C1 to C4	Sum of C1 to C4	Derived from C1–C4
D	Impacts outside the system boundary	Avoided emissions (e.g. recycling credits)	Revenue or avoided cost from recycled materials	End-of-life material recovery data
TOTAL	Whole Life Cycle (WLC)	Total from A1–D	Total from A1–D	Summation of all stages

Table 10 - Cost KPI data inputs

ID	KPI Name	LCA (Kg CO2 Eq.)	LCC (€)	Input source
A1	Raw Material Supply	Input Quantity * embodied emission factor	Input Quantity * construction material costs	Baseline BIM Model
A2	Transport	Emissions from transporting raw materials to the manufacturing site	Costs of transporting raw materials to the manufacturing site	
A3	Manufacturing	Emissions from the manufacturing process	Costs of the manufacturing process	
A1 – A3	Product Stage	Sum of emissions from raw material supply, transport, and manufacturing	Sum of costs from raw material supply, transport, and manufacturing	
A4	Transport	Emissions from transporting the product to the construction site	Costs of transporting the product to the construction site	
A5	Construction & Installation Process	Emissions from the construction and installation process	Costs of the construction and installation process	
A1-A5	Construction stage	Sum of emissions from the entire construction stage	Sum of costs from the entire construction stage	
B1 - B2	Use and Maintenance	Emissions from the use and maintenance of the product	Costs of the use and maintenance of the product	JSON, number (Ratio €/sqm)
B4	Repair	Emissions from repairing the product	Costs of repairing the product	Renovation Planner (list of renovation measures and materials)
B5	Replacement	Emissions from replacing parts of the product	Costs of replacing parts of the product	Renovation Planner (list of renovation measures and materials)
B6	Operational Energy	Emissions from the operational energy use of the product	Costs of the operational energy use of the product	Digital Twin
B1-B7	Use Stage	Sum of emissions from the entire use stage	Sum of costs from the entire use stage	Pilot LCA LCC database
TO TAL	WLC	Total emissions from all stages of the product's lifecycle	Total costs from all stages of the product's lifecycle	

Table 11 - Cost Carbon Benchmark

KPI ID	KPI Name	Short Description	Unit
1	Building Materials Cost (A1-A5 Baseline) + (B4 -B5 Renovated)	Total cost of all materials required for building construction	EUR
2	Yearly Energy Consumption Cost B6	Annual cost of energy consumption for heating, cooling, and electrical appliances	EUR/year
3	Yearly Maintenance Cost	Annual cost for maintenance and repairs to keep the building in operational condition	EUR/year
4	Disposal Cost	Cost for disposal of building materials at the end of their life cycle	EUR
5	Resale Value	Estimated resale value of the building at the end of its life cycle	EUR
6	Carbon Bill	Cost attributed to carbon emissions produced during the building's life cycle	EUR
7	Total Cost LCC	Total life cycle cost including construction, operation, maintenance, and disposal	EUR
8	WLC Cost Performance	Performance indicator measuring the cost-effectiveness of the whole life cycle cost	Ratio
9	Return of Investment	Financial return expected on the investment over the building's life cycle	%
10	Payback Period	Time period required to recoup the initial investment	Years

Table 12 - Balance Assessment (CCBBA)

Input	Unit	Result	Unit
92.207,56 €	€	Cost / Carbon = 1,328	€/ Kg CO ²
69.430,005	Kg CO ² eq		

3.5. Interfaces and API documentation

Overview

The Investment Appraiser API allows the Renovation Planner to send BIM files in .ifc format, renovation and energy demand scenarios, and receive in turn the results for the Life Cycle Costing (LCC), Life Cycle Analysis (LCA) and the relevant costing and environmental KPIs, listed in Deliverable 4.3.

The API is built on Docker and does not have an individual website or interface and is accessible directly through an external port of the server owned and managed by CIRCE.

As for the development of the present document and the examples provided below, dummy data are presented to showcase the complete format of the responses, payloads and files exchanged. All GET and POST methods are deployed and tested and working at full capacity. Some minor revisions may occur as the testing and validation phases proceed within the project to improve efficiency and interoperability in the data exchange communications, but the versions provided below can be considered complete.

Authentication

As for this version of the API, there are no authentication protocols required to access the API.

Base URL and endpoints

The base URL is as follows: [The complete URL is not public due to security concerns \(http://...CHRONICLE/invesment-appraiser/\)](http://...CHRONICLE/invesment-appraiser/)

The current endpoints are the following:

- Endpoint: /results
- Method: GET
- Function: returns the Investment Appraiser LCC, LCA and KPI results in JSON format
- Status codes
- 200: Success
- 400: Server error
- Response:

```
{
  "request_id": "123qwe123",
  "user_id": "456tyu",
  "scenario_id": "789abc",
  "whole_life_carbon":
    {
      "functional_unit": "lifespan",
      "unit": "kgCO2-eq/year",
      "A1": {"baseline": 0, "renovated": 12},
      "A2": {"baseline": 0, "renovated": 11},
      "A3": {"baseline": 0, "renovated": 5},
      "A4": {"baseline": 0, "renovated": 4},
      "A5": {"baseline": 0, "renovated": 5},
      "A1-A5": {"baseline": 0, "renovated": 47},
      "B6": {"baseline": 75, "renovated": 22},
      "B7": {"baseline": 85, "renovated": 15},
      "B6-B7": {"baseline": 160, "renovated": 37},
      "total_balance": {"baseline": 234, "renovated": 123}
    },
  "life_cycle_costing":
```

```

    {
      "functional_unit": "lifespan",
      "unit": "EUR/year",
      "A1": {"baseline": 0, "renovated": 12},
      "A2": {"baseline": 0, "renovated": 11},
      "A3": {"baseline": 0, "renovated": 5},
      "A4": {"baseline": 0, "renovated": 4},
      "A5": {"baseline": 0, "renovated": 5},
      "A1-A5": {"baseline": 0, "renovated": 47},
      "B6": {"baseline": 75, "renovated": 22},
      "B7": {"baseline": 85, "renovated": 15},
      "B6-B7": {"baseline": 160, "renovated": 37},
      "total_balance": {"baseline": 234, "renovated":
123}
    },
    "building_material_cost": {"unit": "EUR", "value": 1235},
    "yearly_energy_baseline": {"unit": "kWh/year", "value": 44},
    "yearly_energy_scenario": {"unit": "kWh/year", "value": 34},
    "yearly_water_baseline": {"unit": "m3/year", "value": 76},
    "yearly_water_scenario": {"unit": "m3/year", "value": 67},
    "resale_value": {"unit": "EUR", "value": 91},
    "total_cost": {"unit": "EUR", "value": 112},
    "wlc_cost_performance": {"unit": "EUR", "value": 456},
    "roi": {"unit": "pct", "value": 0.95},
    "payback_period": {"unit": "year", "value": 5},
    "carbon_bill": {"unit": "EUR", "value": 440},
    "maintenance_cost": {"unit": "EUR", "value": 12},
    "disposal_cost": {"unit": "EUR", "value": 23},
    "cost_carbon_benchmark": {"unit": "EUR/kgCO2-eq", "value": 0.75}
  }
}

```

- Request example (python):

```

import requests
url_path = "The complete URL is not public due to security concerns (
http://...CHRONICLE/invesment-appraiser/ )results"
query = requests.get(url=url_path)
results_json = query.json()

```

- Endpoint: /whole-life-carbon
- Method: GET
- Function: returns the LCA metrics in JSON format
- Status codes:
- 200: Success
- 404: Not found
- Request example (python):

```

import requests
url_path = "The complete URL is not public due to security concerns (
http://...CHRONICLE/invesment-appraiser/ )whole-life-carbon"
query = requests.get(url=url_path)
results_json = query.json()

```

- Endpoint: /life-cycle-costing
- Method: GET
- Function: returns the LCC metrics in JSON format
- Status codes:
- 200: Success
- 404: Not found
- Request example (python):

```
import requests
url_path = "The complete URL is not public due to security concerns \(
http://...CHRONICLE/invesment-appraiser/ \)life-cycle-costing"
query = requests.get(url=url_path)
results_json = query.json()
```

- Endpoint: /upload-ifc
- Method: POST
- Function: upload and store the IFC files
- Status codes:
- 200: Success
- 400: Invalid file type
- Request example (python):

```
file_path = r"./HYP_Testbed.ifc"
with open(file_path, "rb") as f:
    files = {"file": (file_path, f, "application/octet-stream")}
    response = requests.post(url_path, files=files)
```

- Endpoint: /upload-energy-scenario
- Method: POST
- Function: upload and store the JSON energy scenario files
- Status codes:
- 200: Success
- 400: Invalid file type
- Request example (python):

```
import requests
url = "The complete URL is not public due to security concerns \(
http://...CHRONICLE/invesment-appraiser/ \)upload-energy-scenario"
data = {
    "energy": 1,
    "energy2": 2,
    "energy3": 3
}
json_data = json.dumps(data)
response = requests.post(url, json=data)
```

- Endpoint: /upload-renovation-scenario
- Method: POST
- Function: upload and store the JSON energy scenario files
- Status codes:
- 200: Success
- 400: Invalid file type
- Request example (python):

```
import requests

url = "The complete URL is not public due to security concerns \(
http://...CHRONICLE/invesment-appraiser/ \)upload-renovation-scenario"
```

```

data = {
    "buildingElementGroupId": "1QWE",
    "description": "description",
    "renovationMeasureTypeIds": "3ABC"
}
json_data = json.dumps(data)
response = requests.post(url, json=data)

```

- Endpoint: /login-rennovation-planner
- Method: GET
- Function: uploads authentication values to access Rennovation Planner's API
- Status codes:
- 200: Success
- 400: Failure to login.
- Request example (python):

```

import requests
url_path = "The complete URL is not public due to security concerns \( http://...CHRONICLE/invesment-appraiser/ \)login-rennovation-planner"
query = requests.get(url=url_path)
results_json = query.json()

```

3.6. Licensing

No changes over the previous version reported in Deliverable D4.3. A summary has been added as a reference:

Nature of the Code: The Investment Appraiser's source code is closed source and confidential, maintained internally by the development team.

Delivery Form: The application is delivered as a Docker container, ensuring consistent behavior across environments. It operates in the backend without a UI, communicating with the Renovation Planner.

Source Code Repository: The source code is stored in a private GitLab repository, accessible only to authorized team members for secure development and deployment.

Component License: While the backend application itself is closed-source, it utilizes various open-source components, each governed by their respective licenses, including Python Software Foundation License, BSD 3-Clause License, and LGPL-3.0. Specifically, it uses Python, Pandas, and IFCOpenshell.

4. Integration Testing

In this section additional details are provided on the integration testing cases also reported in deliverable D5.1 - ANNEX II for the integration of the Renovation Planner and the Investment Appraiser. More specifically, two distinct integration cases were identified for the cooperation of the two tools and those are detailed below along with their updates.

Table 13 The Renovation Planner forwards the Baseline and Renovation scenario data to the Investment Appraiser

Test name	Send the baseline and renovation scenario data to the Investment Appraiser.
Test ID	IA_00
Components	Renovation Planner – Investment Appraiser
Objective	The Renovation Planner must successfully send the baseline .ifc file, the generated renovation scenarios to the Investment Appraiser.
Prerequisites	<p>Test ID CDE_02 must be successful (detailed in D5.1).</p> <p>Renovation scenarios are generated and available within the Renovation Planner.</p> <p>The energy indicators for the renovation measures, generated renovation scenarios and for the baseline are available and stored within the Renovation Planner.</p>
Test data	<p>Data type and format necessary for the test completion - actual values are not necessary at this point, dummy data can be used.</p> <p>HYP's testbed .ifc file</p> <p>Renovation scenarios for the HYP's testbed (Changesets) in json format.</p> <p>Energy indicators for the HYP's testbed and the renovation scenarios/measures stored in the Renovation Measures Catalogue.</p>
Test Setup	<p>POST endpoint provided by the Investment Appraiser's API</p> <p>Renovation Planner V1.0</p> <ul style="list-style-type: none"> • Operating System: Linux • Angular Version: 15.2 • Python Version: 3.11 • Node.js Version: 18.10 • MongoDB Version: 8.0 <p>Investment Appraiser V1.0</p> <ul style="list-style-type: none"> • Operating System: Windows 11 • Python Version: 3.18 • MongoDB Version: 8.0

Test Methodology	<ul style="list-style-type: none"> • The Renovation Planner sends the .ifc openBIM model in IFC4 STEP format for the baseline scenario, the generated renovation scenarios .in json format and the baseline to the Investment Appraiser via an API. • The Investment Appraiser has successfully retrieved the files from the API call and the energy indicators for the generated renovation scenarios from the Renovation Measures Catalogue and begins calculating/simulating WLC and Cost KPIs.
Pass criteria	<p>The .ifc openBIM model in IFC4 STEP format for the baseline scenario, the generated renovation scenarios in json format and the energy indicators for the baseline and the generated scenarios files are available to the Investment Appraiser.</p>
Results	<p>To be provided per component in D5.2.</p>

Table 14 The Renovation Planner receives the WLC/Cost KPIs, the Carbon Bill and the Carbon Benchmark Balance Assessment from the Investment Appraiser

Test name	Receive the calculated/simulated data from the Investment Appraiser.
Test ID	IA_01
Components	Investment Appraiser – Renovation Planner
Objective	The Renovation Planner must successfully receive the calculated/simulated WLC/Cost KPIs, the Carbon Bill and the Carbon Benchmark Balance Assessment
Prerequisites	Test ID IA_00 must be successful
Test data	Calculated WLC/Cost KPIs based on HYP's Testbed in json format.
Test Setup	<p>POST endpoint provided by the Investment Appraiser's API</p> <p>Renovation Planner V1.0</p> <ul style="list-style-type: none"> • Operating System: Linux • Angular Version: 15.2 • Python Version: 3.11 • Node.js Version: 18.10 • MongoDB: 8.0 <p>Investment Appraiser V1.0</p> <ul style="list-style-type: none"> • Operating System: Windows 11 • Python Version: 3.18 • MongoDB Version: 8.0
Test Methodology	Upon calculating the WLC/Cost KPIs, the Carbon Bill and the Carbon Benchmark Balance Assessment, the Investment Appraiser responds to the Renovation Planner with these calculations in a json format.
Pass criteria	The calculated/simulated WLC/Cost KPIs, the Carbon Bill and the Carbon Benchmark Balance Assessment are available to the Renovation Planner.
Results	To be provided per component in D5.2.

The integration testing cases between the Renovation Planner and the CDE proceed as reported in D5.1 so there are no further updates to present in this document.

5. ChroViewRen User Interface Walkthrough

This section gives a complete look, through screenshots, at the MVP version of the user interface used by the Renovation Planner and the Investment Appraiser, namely the ChroViewRen. This walkthrough can also be considered as a user manual for the software as details and step explanations are provided under each screenshot, showcasing all the functionalities and results an end-user can achieve. For this walkthrough the user role of Engineer (Admin) will be used as this role includes all the available functionalities of the ChroViewRen, so all the screens included belong to the Engineer's view. Additionally, the informative screen of the Tenant user role will be presented. Finally, the example process shown in the walkthrough is based on the HYPERTECH Test Bed, which is also presented in deliverable D5.1.

User registration – Login screens

Figure 6 - ChroViewRen Registration page



Figure 7 - ChroViewRen Login page



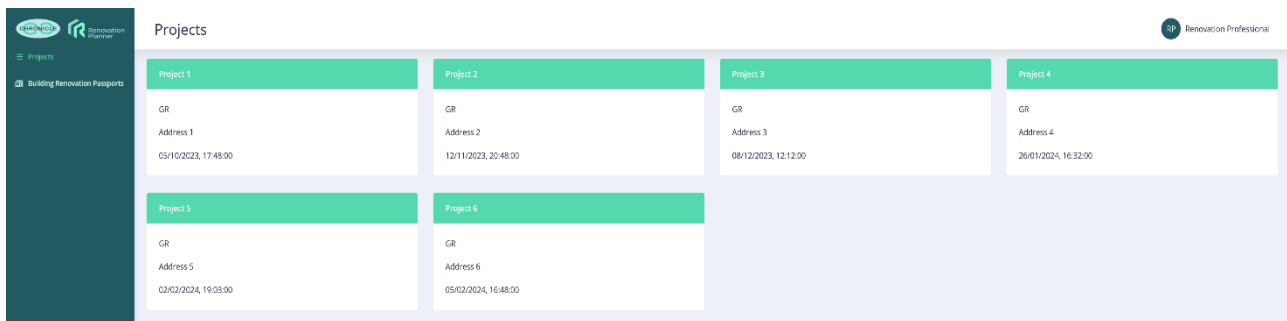
The registration form, shown in Figure 6, requires the new user to input their respective:

- First and Last name
- Username
- Password
- Email address
- Country of origin
- Profession/Speciality
- Organization name (optional)
- Role (Tenant or Engineer)

The login page, shown in Figure 7, requires the user to provide their credentials (username/password) to access the tool, while also providing the capability for new users to create and register their account by clicking on the *Register* tab.

Projects screen

Figure 8 - ChroViewRen Projects screen



As soon as the Engineer inputs their credentials and logs in to the tool, the Projects screen appears, shown in Figure 8, where all their available and associated renovation projects, along with some of their details like Country, City and Date, are listed. By clicking on one of them (in this walkthrough we select Project 1), the tool leads the user to the next screen, namely the Project Overview screen.

Project Overview screen

Figure 9 - ChroViewRen Project Overview screen

Overview

Project: Project 1
File: project.ifc

Country: GR
Address: Address 1

Building Height: 6.65 m
External Wall Area: 300000 m²
Usable Floor Area: 620000 m²

MATERIAL PROPERTIES

ENERGY PRICES & EMISSIONS

ENVIRONMENTAL COSTS

Filter

ID	Name	Layer Thickness	Absorptance	Heat Transfer Coefficient (U)	Roughness	Thermal Mass	Thermal Resistance (R)
2423	HOR_Mortero cemento TERM (A=0.55 W/mk)	0.15	-	-	-	-	-
4161	Wood -JELD-WEN - Custom Wood Species (For Clad Window)	0.015	-	-	-	-	-
4165	HOR_Hormigon armado TERM (A=2.3 W/mk)	0.05	-	-	-	-	-
4172	REV_Enlucido yeso TERM (A=0.57 W/mk)	0.01	-	-	-	-	-
11903	Vinyl-PlyGem-Beige	0.001	-	-	-	-	-
12002	<Unnamed>	0.1	-	-	-	-	-
47673	Analytical Surface - Roofs	0.3048	-	-	-	-	-
2490	HOR_Mortero cemento TERM (A=0.55 W/mk)	-	0.7	2.75	3	303.6	0.3636
2632	HOR_Mortero cemento TERM (A=0.55 W/mk)	-	0.7	1.5714	3	531.3	0.6364
2690	HOR_Mortero cemento TERM (A=0.55 W/mk)	-	0.7	2.2	3	379.5	0.4545
2946	HOR_Mortero cemento TERM (A=0.55 W/mk)	-	0.7	5.5	3	151.8	0.1818
4605	HOR_Mortero cemento TERM (A=0.55 W/mk)	-	0.7	2	3	417.45	0.5
4708	HOR_Mortero cemento TERM (A=0.55 W/mk)	-	0.7	3.6667	3	227.7	0.2727
4222	HOR_Hormigon armado TERM (A=2.3 W/mk)	-	0.1	3.8152	1	446.6329	0.2621
11946	HOR_Hormigon armado TERM (A=2.3 W/mk)	-	0.1	7.2395	1	426.3045	0.1371
47786	HOR_Hormigon armado TERM (A=2.3 W/mk)	-	0.1	46	1	75.555	0.0217

Items per page: 20 1 - 16 of 16

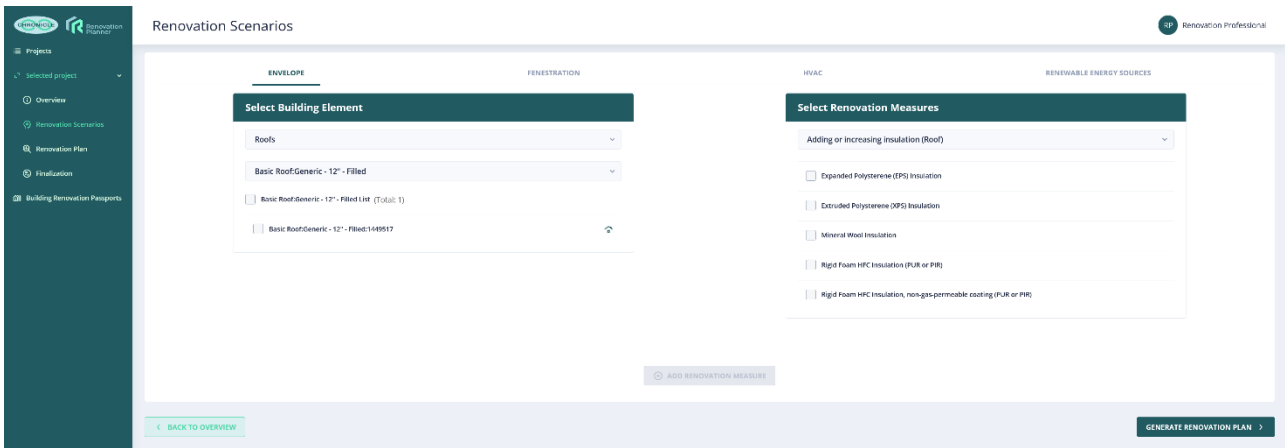
BACK TO PROJECTS GO TO RENOVATION SCENARIOS

On the Project Overview screen, shown in Figure 9, the user can see all the details regarding the baseline status of the building to be renovated. Specifically, they can see information regarding the building's height, external wall area, usable floor area as well as the country and city where it is located and the IFC file used to parse and produce all the baseline information. Additionally, the screen includes three tabs, namely the Material Properties, the Energy Prices & Emissions and Environmental Costs that include related information based on the building's baseline operations, consumptions and structural/system elements' details. In Figure 9, the Material Properties tab is selected, where the user can see all the materials used in the building. Those include details, like the layer thickness, if they are used in the layers of the stratigraphy of the building's walls, floors, roof, and their thermal properties, namely the Absorptance, Heat Transfer Coefficient (U), Roughness, Thermal Mass and Thermal Resistance (R). This screen can be used by the Engineer to get a complete overview of the building status as is, to then proceed to the renovation planning by click on the GO TO RENOVATION SCENARIOS button, which will lead them to the next page.

Renovation Scenarios screen

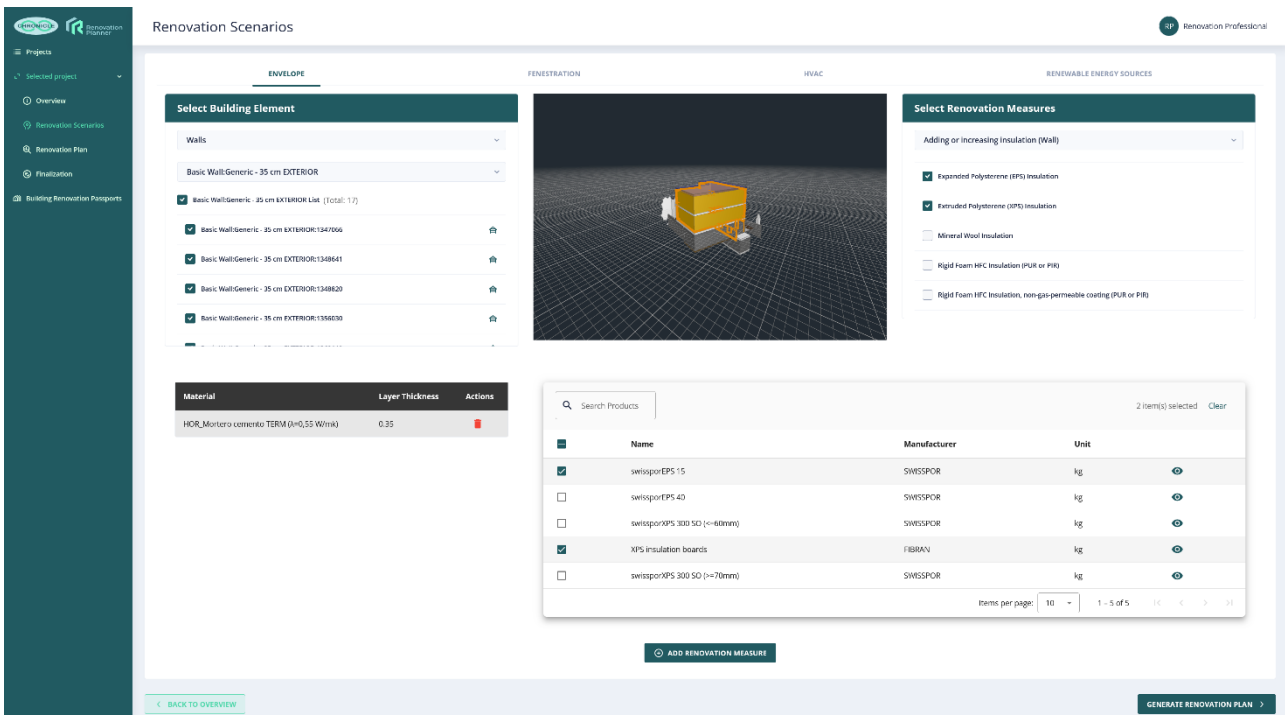
In the Renovation Scenarios screen, shown in Figure 10, the Engineer can see four tabs, namely the Envelope, the Fenestration, the HVAC and the Renewable Energy Sources tabs, which include the building's structural and system elements grouped by their type. Based on the building element group type the user wants to apply renovation measures, they can select the corresponding tab and then from the drop-down menu under the Select Building Element indication, they can select the exact element group of interest.

Figure 10 - (a) ChroViewRen Renovation Scenarios screen



In Figure 11, the user, under the Envelope tab, has selected the Walls as the building element group of interest and more specifically, they have selected all the exterior walls of the building. Their selection is also shown in the viewer by highlighting all the selected building elements. By selecting the exterior walls of the building, an informative box regarding those walls' layers also appears, presenting the layers included in those walls along with their materials. The user is enabled to delete the layers, if they wish to and if they intend to substitute them with new materials/layers because of the renovations. Under the Select Renovation Measures indication, the user has selected the *Adding or increasing insulation (Wall)* measure and their preferred insulation material/product families, namely the EPS and the XPS. The latter selection has popped up the products' box straight under which includes all the available EPS and XPS products in the Renovation Measures Catalogue database and the user selects two of them, namely the swisspor EPS 15 and the XPS insulation boards by FIBRAN.

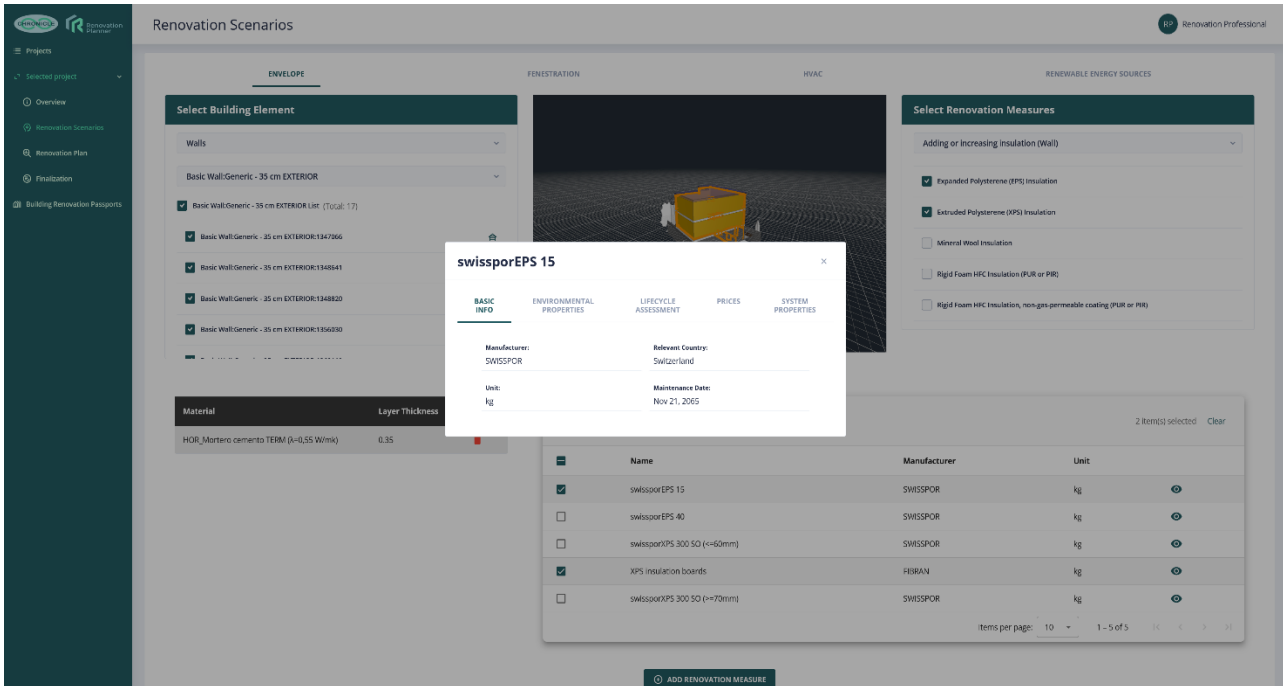
Figure 11- (b) ChroViewRen Renovation Scenarios screen



By clicking on the eye icon on the right of each of the available products, a pop-up informative box appears, shown in Figure 12, where all the relevant details of the selected product are listed. These

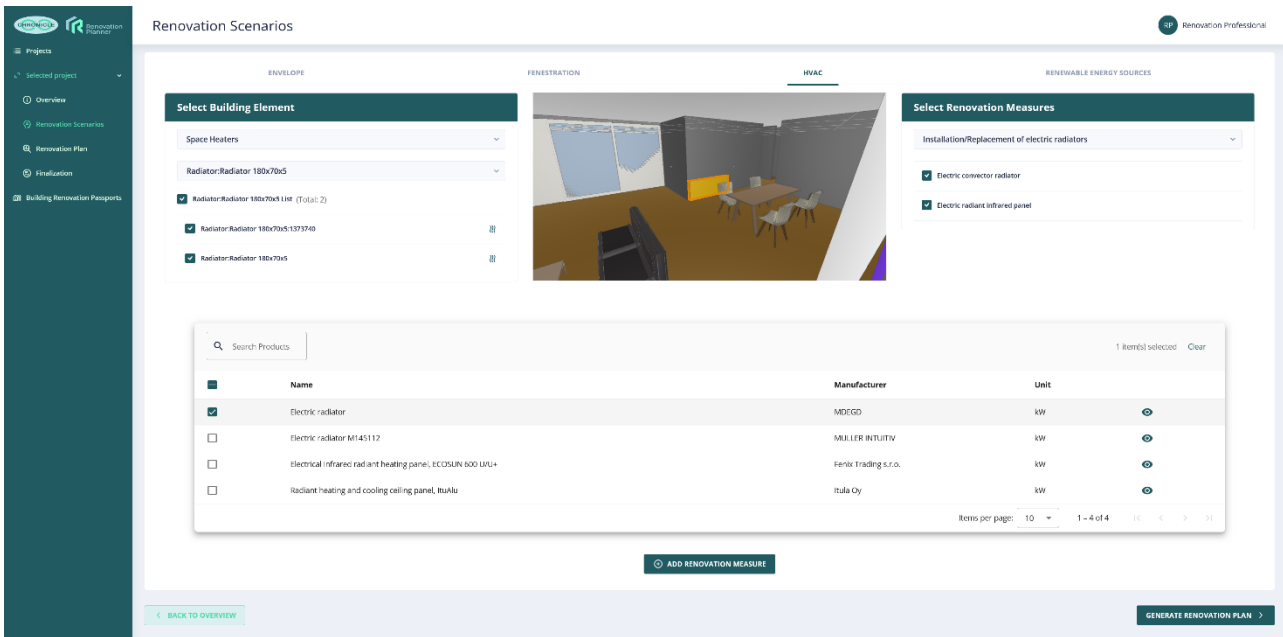
details concern basic information, environmental properties, lifecycle assessment values, prices and system properties, if the selected product is a system. Finally, the user must click on the **ADD RENOVATION MEASURE** button to add their selected renovation measure along with the selected products to the pool of renovation scenarios that will be used when generating the potential renovation plans as the process proceeds.

Figure 12 - (c) ChroViewRen Renovation Scenarios screen



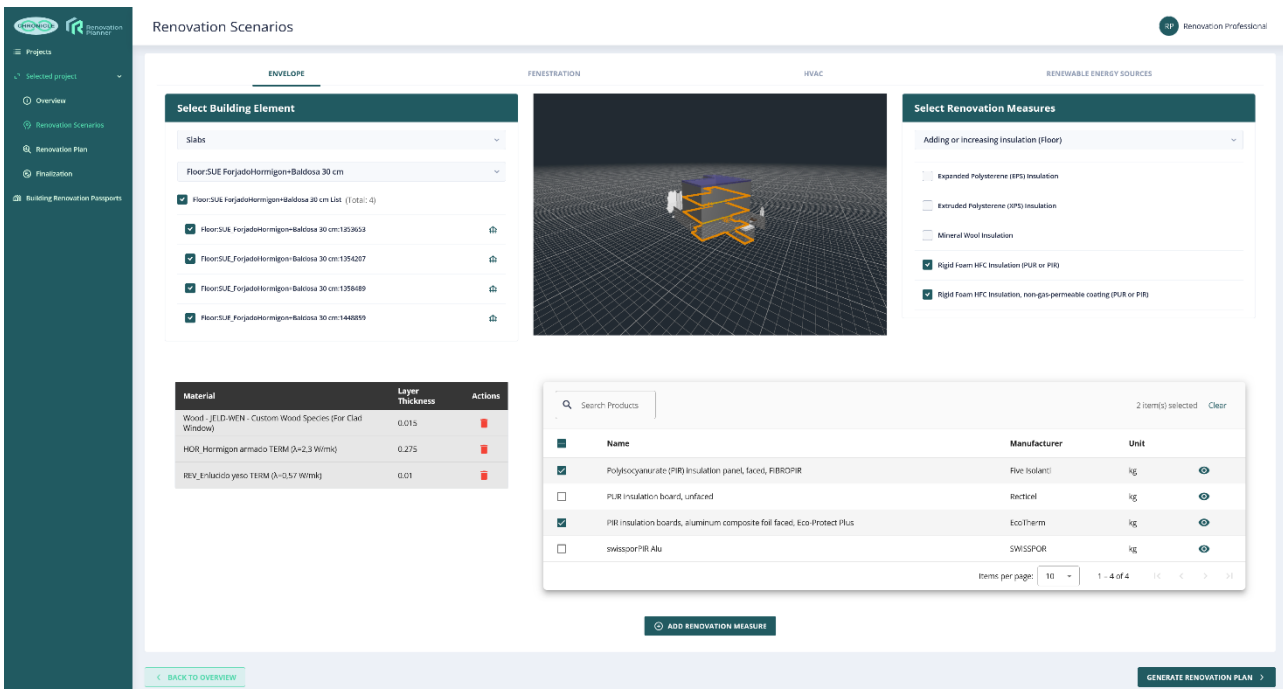
In Figure 13, the user has selected the HVAC tab and like above, has also selected the Space Heaters as the building element group of interest and more specifically, two radiators included in the building. These again are highlighted in the modeler (in the screenshot we have zoomed in on one of them). Then the user has selected the *Installation/Replacement of electric radiators* renovation measure and their preferred electric radiator product families, namely the Electric convector radiator and the electric radiant infrared panel. From the available products belonging to those families, the user has selected the Electric radiator by MDEGD and has clicked on the **ADD RENOVATION MEASURE** button to store their selection on the renovation scenarios pool.

Figure 13 - (d) ChroViewRen Renovation Scenarios screen



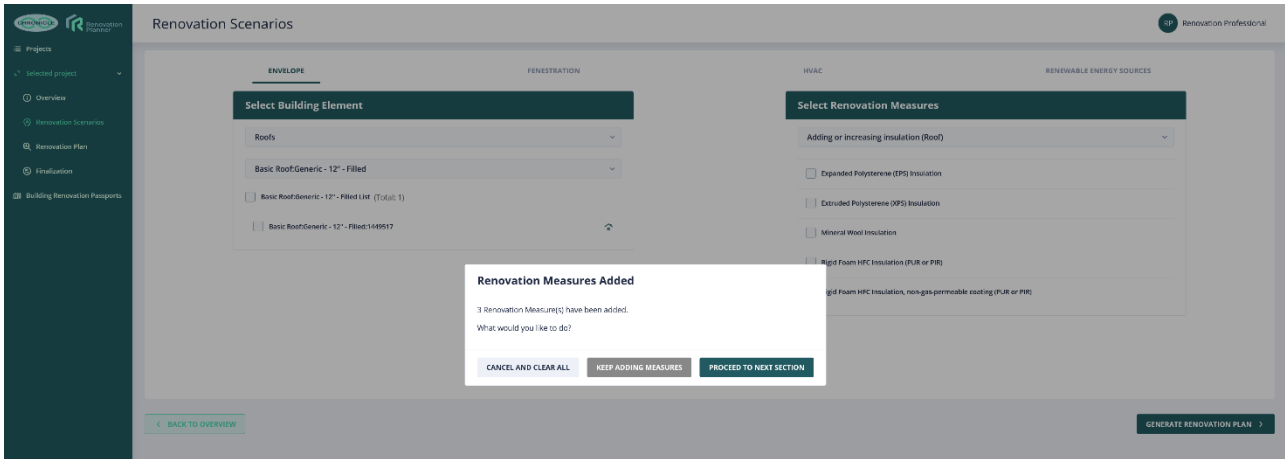
In Figure 14, the user has again selected the Envelope tab, but this time they have selected the Slabs as the building element group of interest and the floors of the building as shown in the modeler. The layers included in those floors are provided in the corresponding information box along with the materials used and their thickness. The user has selected the *Adding or increasing insulation (Floor)* renovation measure and the Rigid Foam HFC Insulation (PUR or PIR) and the Rigid Foam HFC Insulation, non-gas-permeable coating (PUR or PIR) product families. Then, as above, the available products of those families appear of which the user has selected the PIR insulation panel, faced, FIBROPIR by Five Isolanti and the PIR insulation boards, aluminum composite foil faced, Eco-Protect Plus by Ecotherm as their preferred products and has clicked again on the **ADD RENOVATION MEASURE** button.

Figure 14- (e) ChroViewRen Renovation Scenarios screen



After having made all their selections, the user proceeds by clicking on the **GENERATE RENOVATION PLAN** button, which causes the pop-up shown in Figure 15 to appear. This pop-up informs them on the number of renovation measures they have added to the pool and asks for a confirmation before continuing to renovation plans generation. By selecting proceed, the tool leads the user to the Renovation Plans screen.

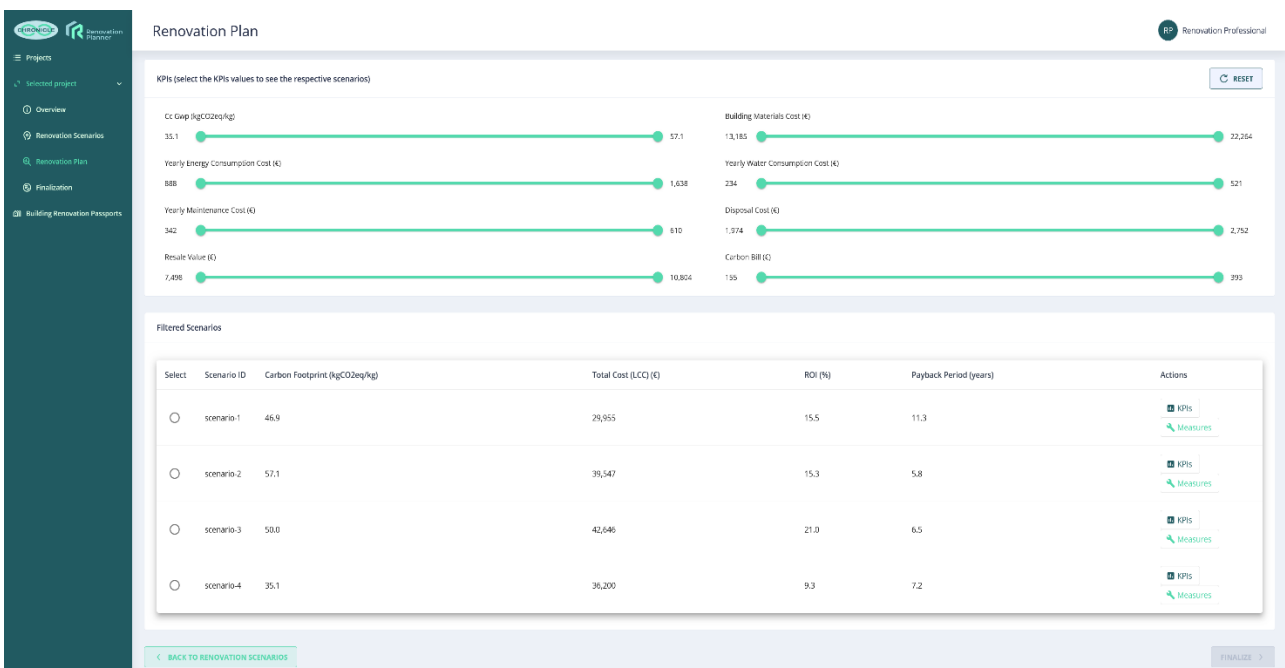
Figure 15 - (f) ChroViewRen Renovation Scenarios screen



Renovation Plans screen

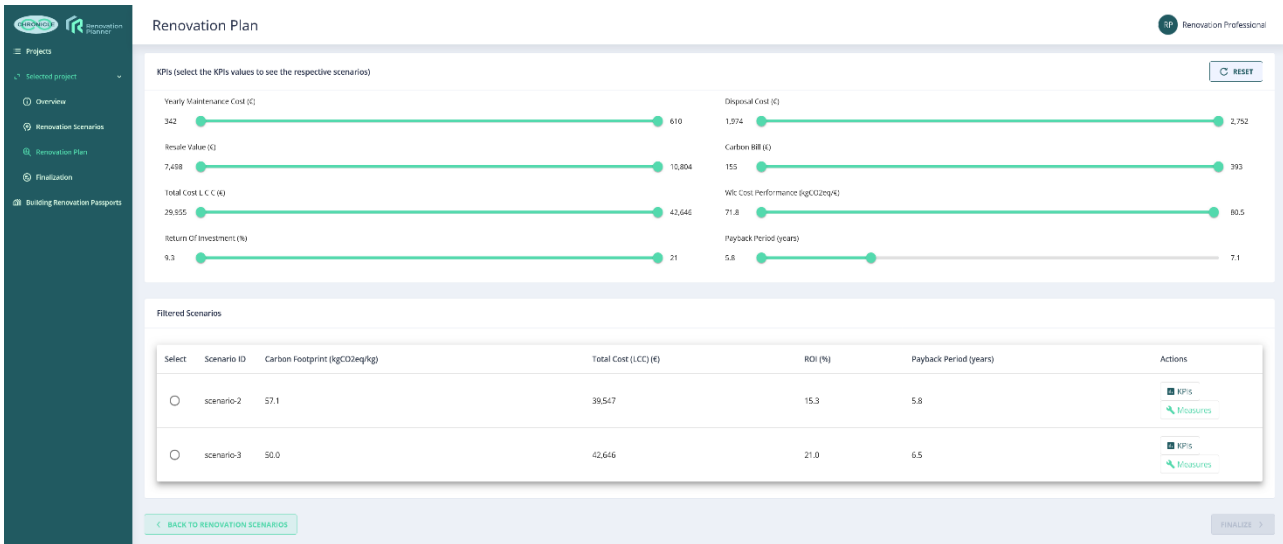
In the Renovation Plans screen, shown in Figure 16, all the generated Renovation Plans are presented to the user. They can be filtered by using the *KPIs* box, where the user can inspect all the potential KPIs describing the post-renovation state of the building. Those KPIs are presented in the scroll bar format shown in Figure 16, with their minimum potential value shown at the start of the bar and the maximum one at the end

Figure 16 - (a) ChroViewRen Renovation Plans screen



By scrolling through the bar of each KPI, as done in Figure 17 with the *Payback Period (years)* KPI, the user can select the exact values they want to achieve within the provided min-max range for each KPI that interests them the most for the type of renovation they want to plan. When doing that, the contents of the *Filtered Scenarios* box will change, and instead of showing all the generated Renovation Plans, it will only show the plans that respect the KPIs' values that the user has selected through their filtering.

Figure 17 - (b) ChroViewRen Renovation Plans screen



Furthermore, each renovation plan has its own *KPIs* and *Measures* buttons, which present all the associated KPIs and renovation measures included in the potentially selected renovation plan, as shown in Figures 18 and 19, respectively.

Figure 18 - (c) ChroViewRen Renovation Plans screen

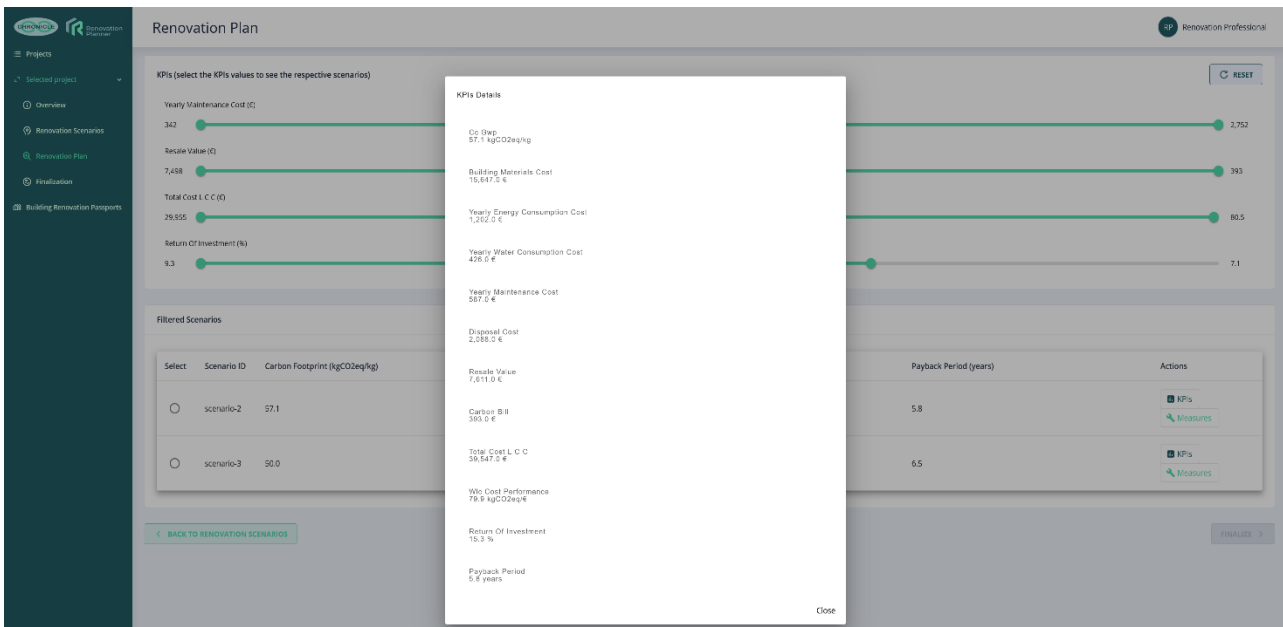
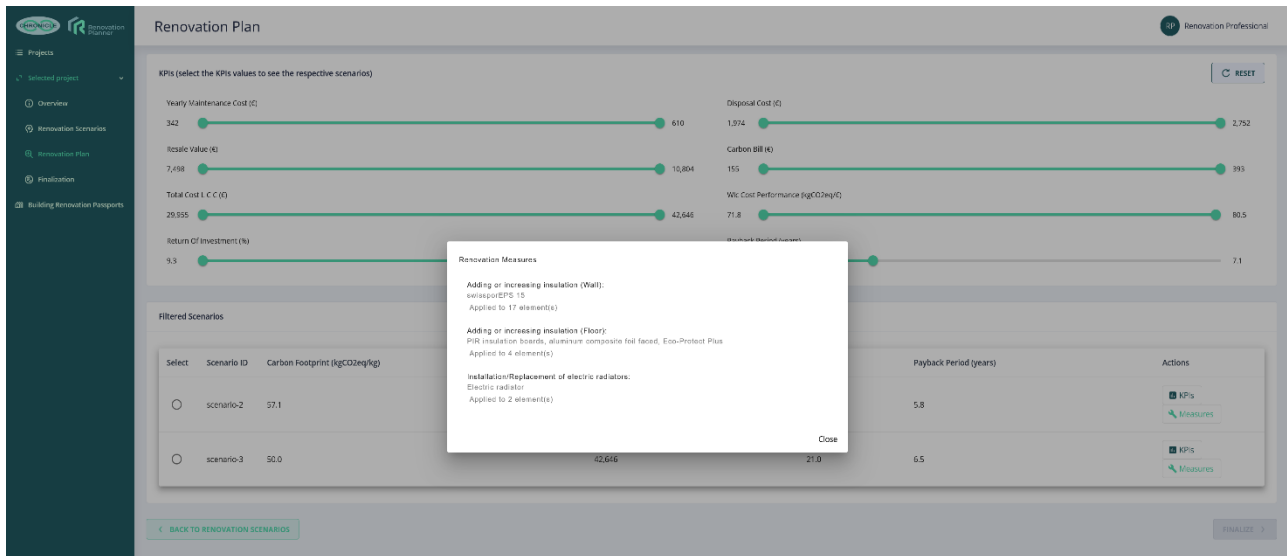


Figure 19 - (d) ChroViewRen Renovation Plans screen



Finally, when the user has made a definitive selection on which plan they want to follow for their renovation project, they proceed to the Finalization screen by clicking on the *Finalize* button.

Finalization screen and Building Renovation Passport

In the Finalization screen, shown in Figure 20, all the renovation measures that belong to the renovation plan selected by the user are listed along with their details. Relevant maintenance details are also provided, where available, and the user is enabled to also provide their own maintenance details, if they wish to do so. Furthermore, *additional information* text boxes are provided in which the user can include information about the renovation in text format, such as details of the required permits, approvals, contractors and public/private renovation-related grants.

Figure 20 – ChroViewRen Finalization screen

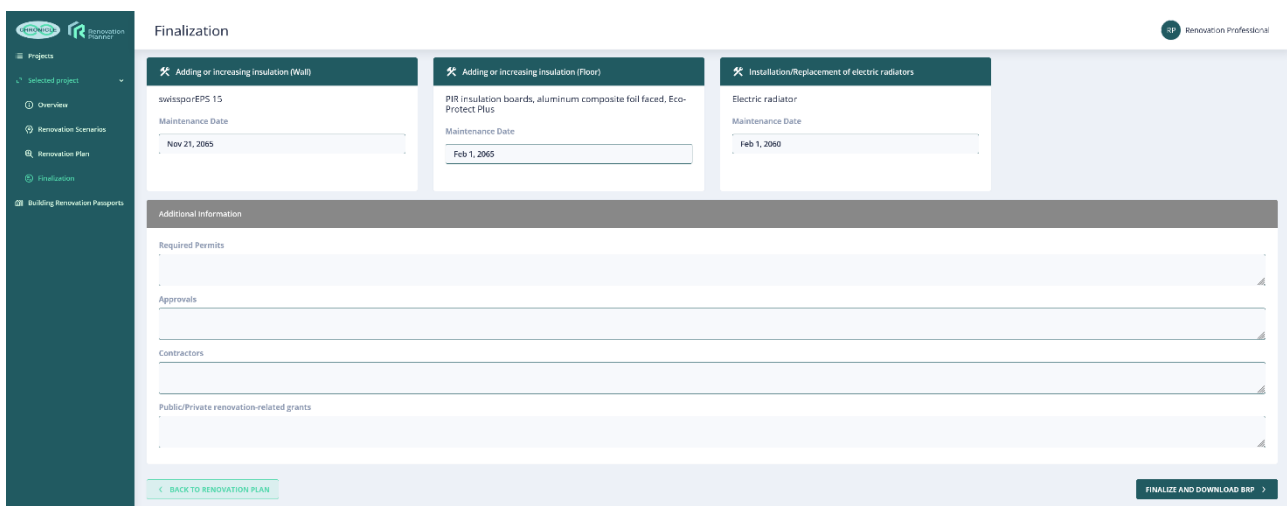
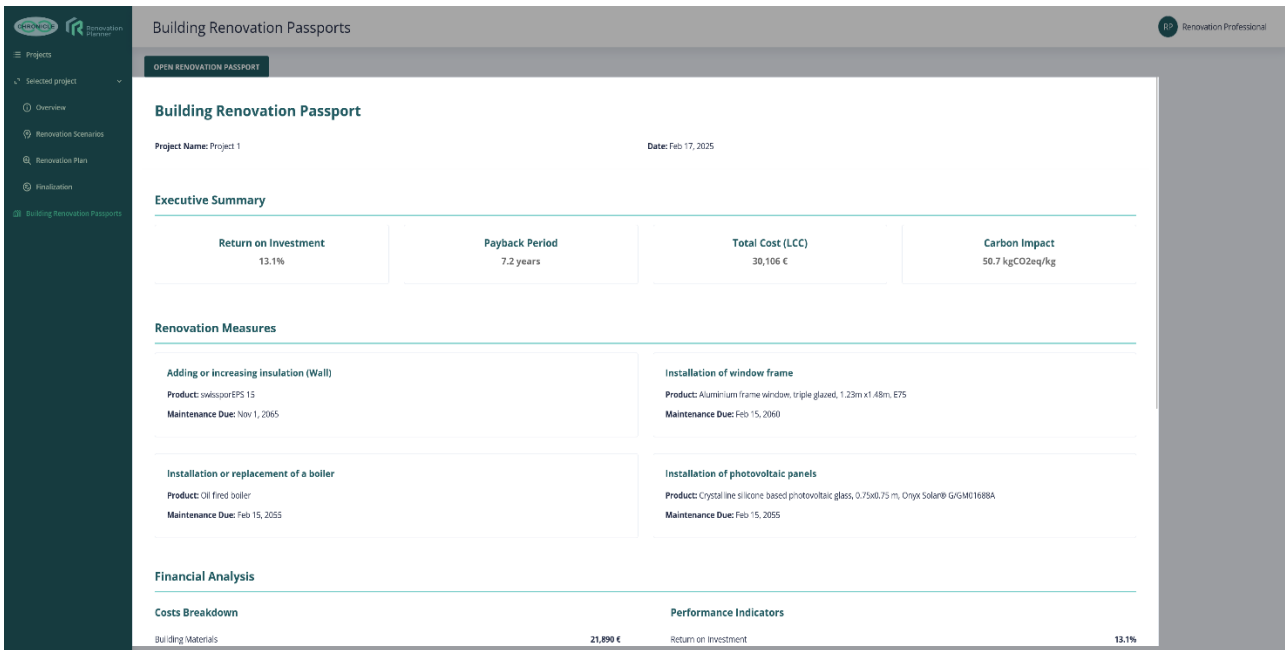


Figure 21 - ChroViewRen BRP

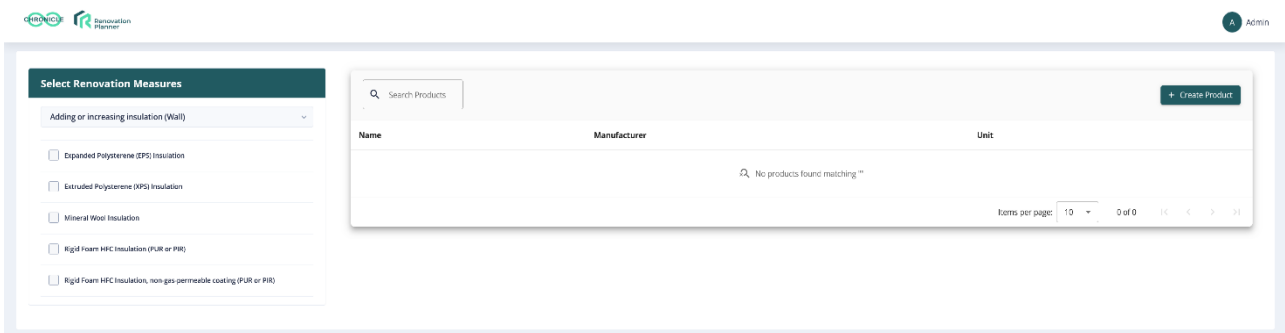


The user can finalize the process by clicking on the Finalize and download BRP button, which will download the BRP in PDF format to their device. The Building Renovation Passport will include and present all the information and details described in the Finalization screen along with an executive summary and associated KPIs of the selected renovation plan, as shown in Figure 21.

Admin screen

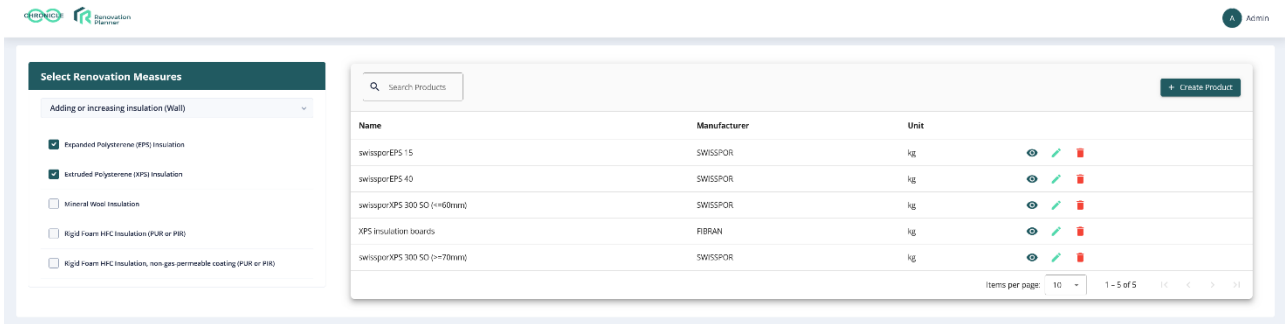
The Engineer role also has access to the Admin screen, shown in Figure 22, which permits the user to have an overview of all the available renovation measures and products/materials in the Renovation Measures Catalogue database.

Figure 22 - (a) ChroViewRen Admin screen



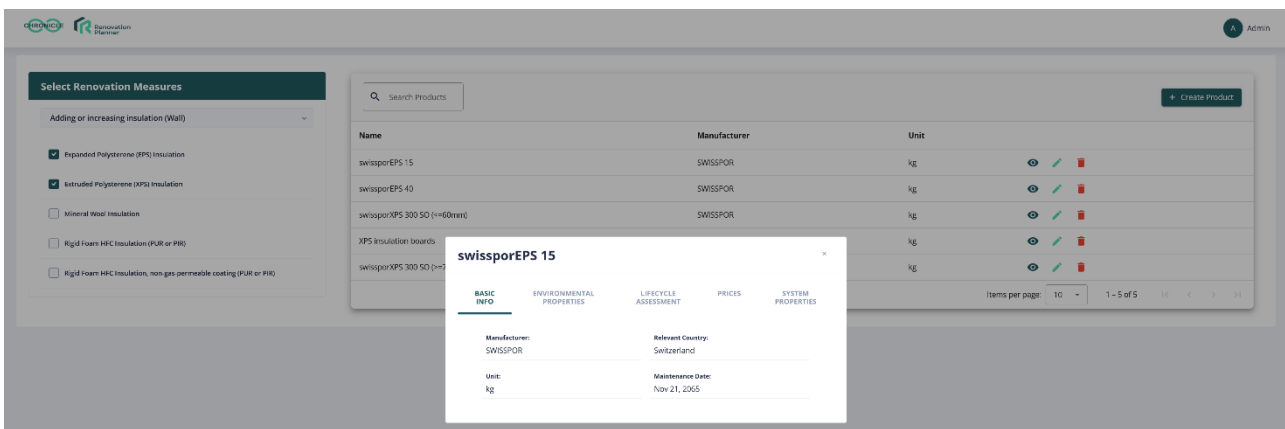
In Figure 23, the user has selected the *Adding or increasing insulation (Wall)* renovation measure from the drop-down list of available renovation measures and has selected the EPS and XPS insulation material families to inspect all the available EPS and XPS products.

Figure 23 - (b) ChroViewRen Admin screen



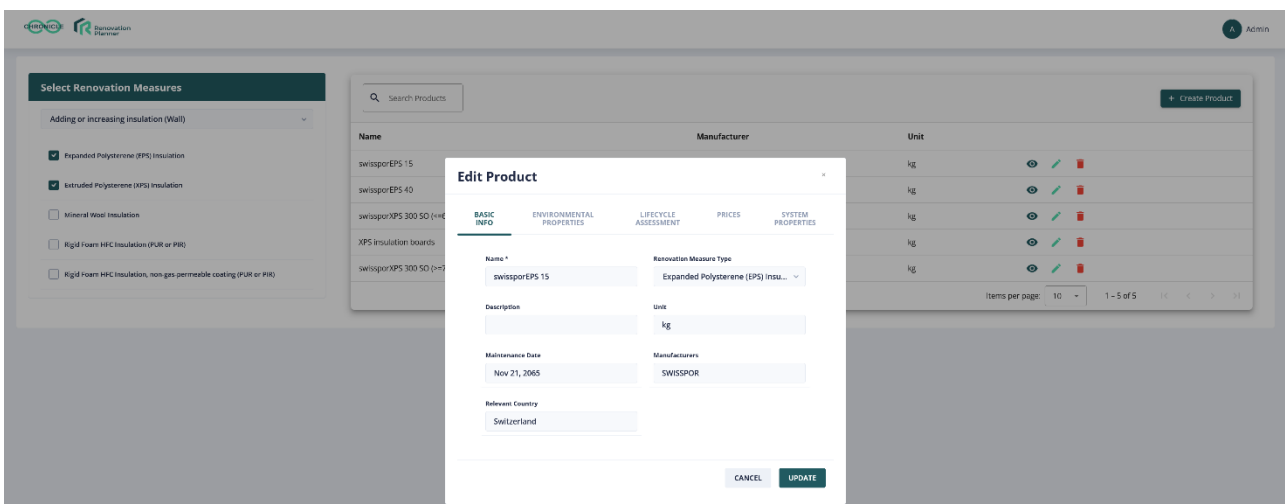
By clicking on the eye icon next to a product, as done in Figure 24, a pop up information box appears with all the available information on the selected product.

Figure 24 - (c) ChroViewRen Admin screen



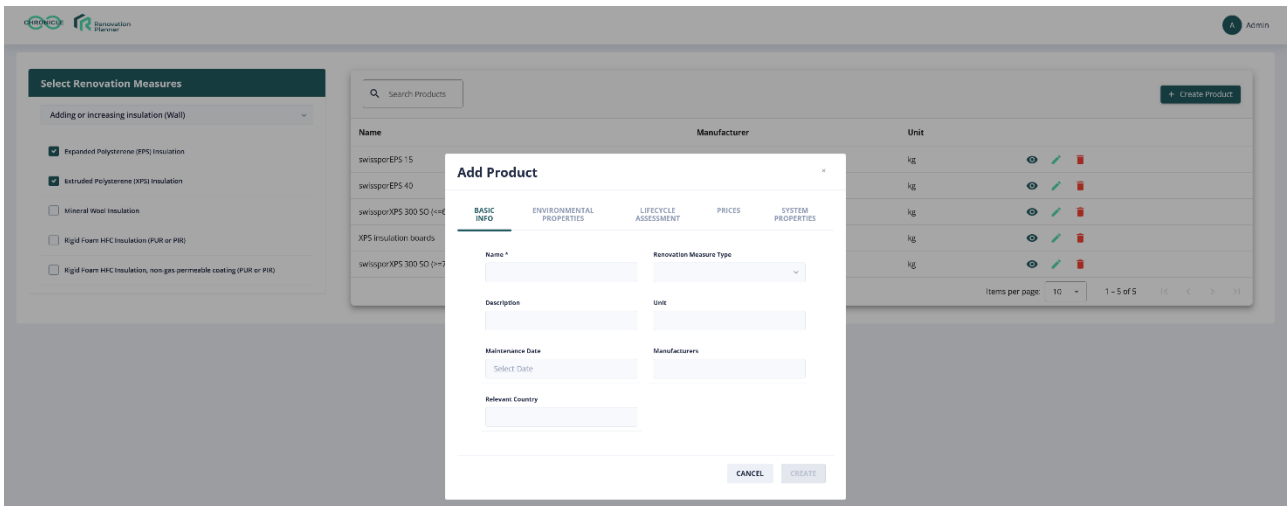
By clicking on the pencil icon next to a product, an *Edit Product* pop-up box appears, as shown in Figure 25, where the user can edit and modify all of the product's information based on their own expertise and knowledge and store these changes to the database so that the products have the values they deem correct for their needs and localization.

Figure 25 - (d) ChroViewRen Admin screen



By clicking on the Create Product button, the user can store a completely new product in the database by providing all its information and associate it with an available renovation measure, as shown in Figure 26.

Figure 26 - (e) ChroViewRen Admin screen



Finally, on this screen the user can also delete a product from the database by clicking on the red icon.

Tenants' screen

The Tenant user role has exclusive access to the Tenants' screen presented in Figures 27, 28 and 29 after they have logged in with their credentials as shown in Figure 6. The Tenants' screen's objective is to be informative and report on everything renovation-related for the building the logged-in tenant is associated with. Consequently, the user can first learn about the baseline KPIs of their building prior to the renovation as presented in Figure 27 and then be informed about their building's post-renovation KPIs as shown in Figure 28.

Figure 27 - (a) Tenants' screen

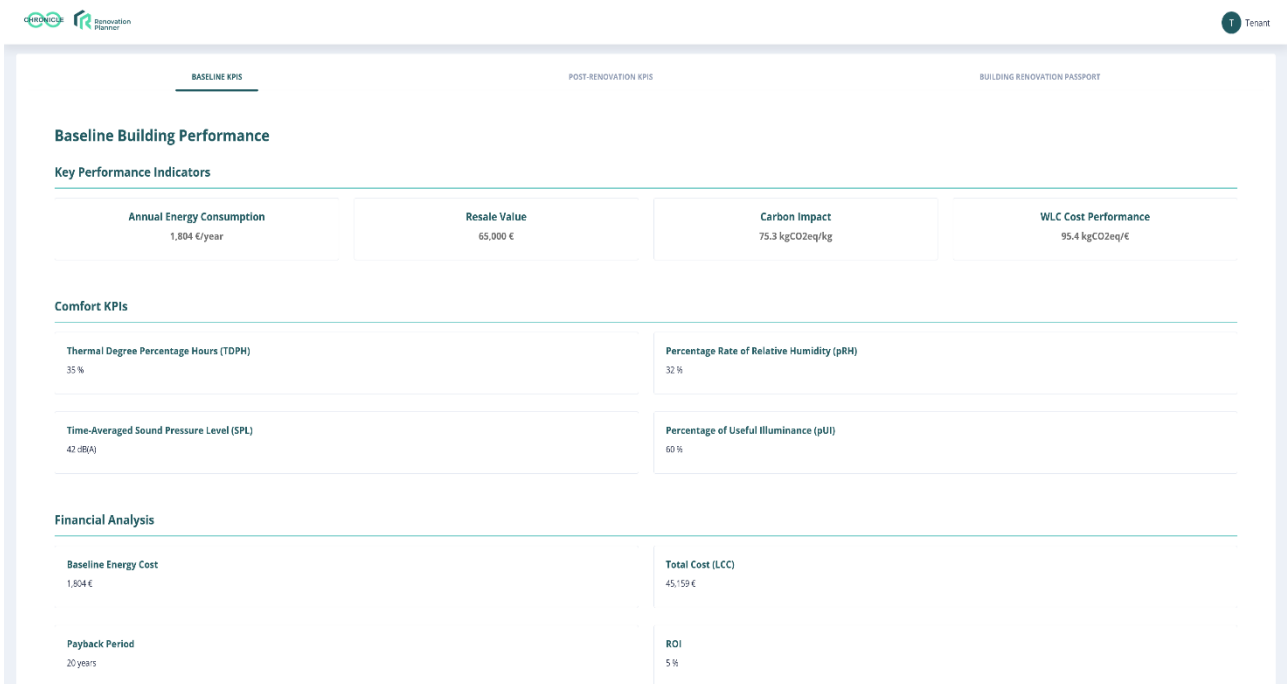
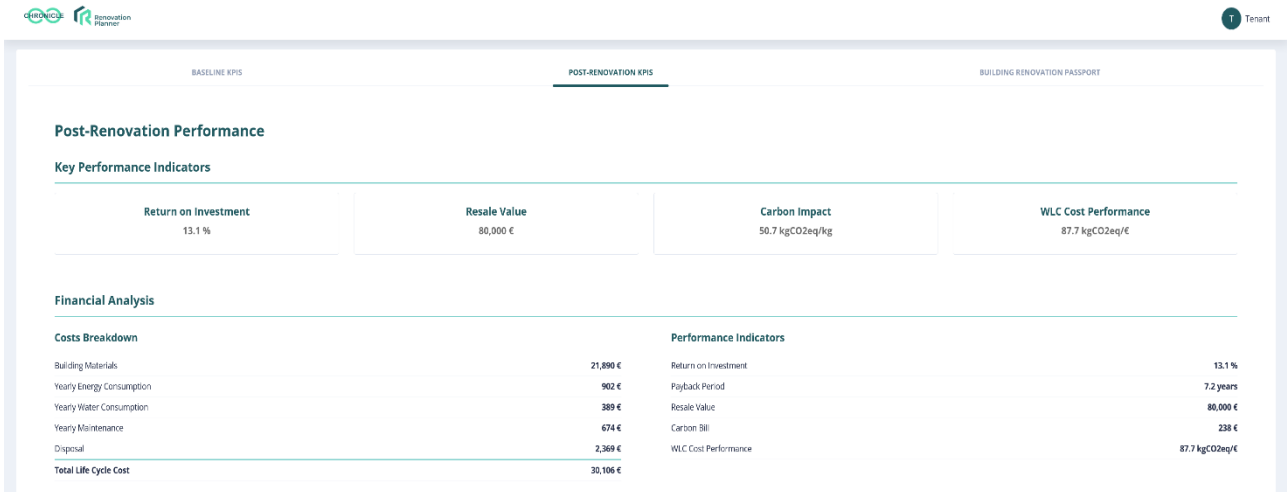
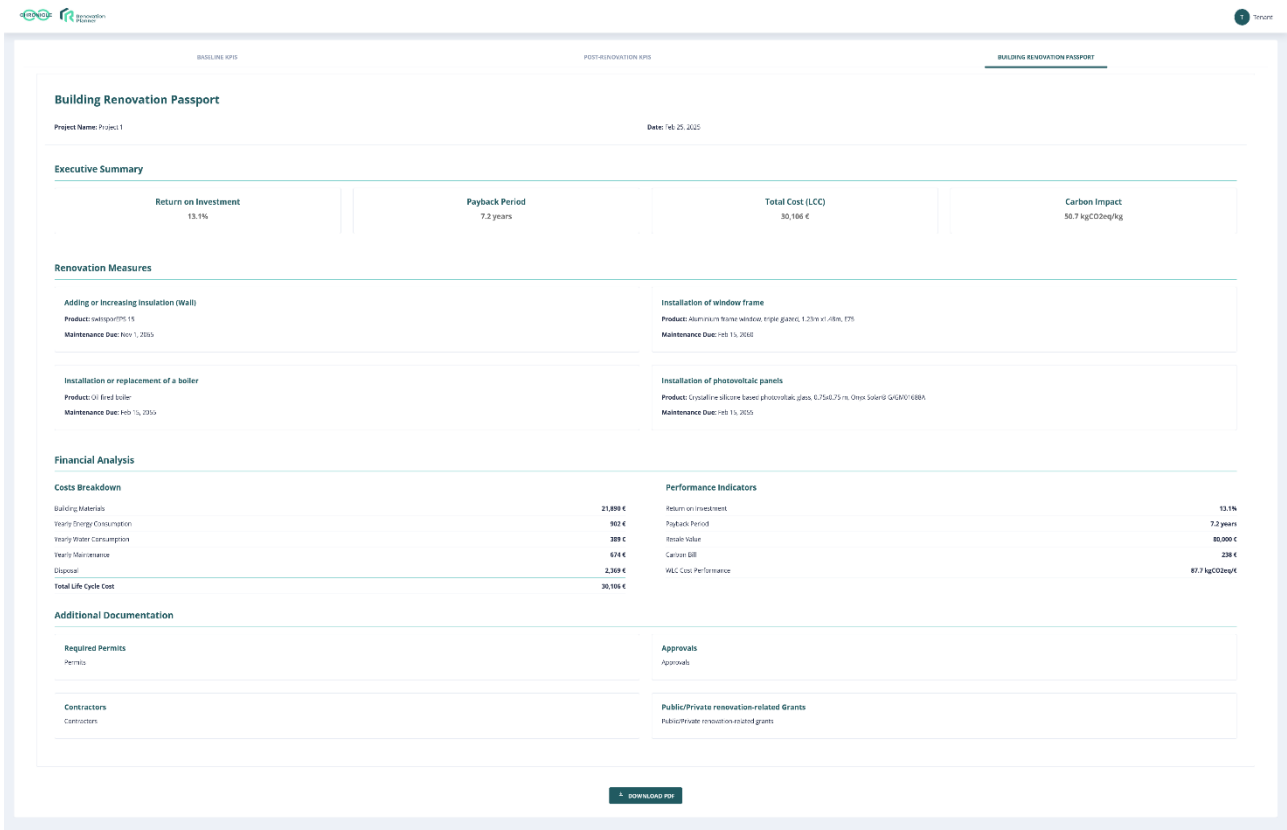


Figure 28 – (b) Tenants' screen



Finally, by clicking on the Building Renovation Passport tab, shown in Figure 29, the tenant can read the BRP generated by the Renovation Planner for the renovation plan designed for their building by the Engineer.

Figure 29 - (c) Tenants' screen



6. Conclusions

The current updated version of the CHRONICLE tool suite for WLC assessment and climate neutral building renovation planning deliverable reports the complete definition, design and methodological framework of the Renovation Planner and the Investment Appraiser tools. All those aspects belong to the work done in the two major development tasks T4.3 and T4.4 but many of those are also first defined, at a higher level, in the various tasks of WP2 and WP3, namely tasks T2.1, T2.2, T2.4 and T3.1.

In this deliverable a definitive and in-depth overview is provided for the two tools including their MVP versions and a detailed walk-through of their UI functionalities and operation. The components' definitions provide their fully developed architectural schemas including descriptions of their respective subcomponents. Furthermore, the methodological approach behind the definition and design of those subcomponents is summarized. Additionally, major technical and development updates are included for the two tools, namely the final technology stack and implementation tools used, their input and output parameters, the available interfaces and API documentation and their licensing.

Finally, no other major updates or revisions are expected in the design or development of the Renovation Planner and the Investment Appraiser as the project proceeds in its testing and validation phases, expecting their results to be reported in D5.2.

7. Annexes

7.1. Annex 1: Renovation Measures Catalogue (simplified version - current state)

Material/Product Category	Material/Product Name	Used in Renovation Measures
Extruded Polysterene (XPS) Insulation	swissporXPS 300 SO (<=60mm)	Adding or increasing insulation (Wall), Adding or increasing insulation (Floor), Adding or increasing insulation (Roof)
Extruded Polysterene (XPS) Insulation	XPS insulation boards	Adding or increasing insulation (Wall), Adding or increasing insulation (Floor), Adding or increasing insulation (Roof)
Extruded Polysterene (XPS) Insulation	swissporXPS 300 SO (>=70mm)	Adding or increasing insulation (Wall), Adding or increasing insulation (Floor), Adding or increasing insulation (Roof)
Expanded Polysterene (EPS) Insulation	swissporEPS 15	Adding or increasing insulation (Wall), Adding or increasing insulation (Floor), Adding or increasing insulation (Roof)
Expanded Polysterene (EPS) Insulation	swissporEPS 40	Adding or increasing insulation (Wall), Adding or increasing insulation (Floor), Adding or increasing insulation (Roof)
Mineral Wool Insulation	Mineral (glass and stone) wool insulation rolls, single side black glass fiber facing	Adding or increasing insulation (Wall), Adding or increasing insulation (Floor), Adding or increasing insulation (Roof)
Mineral Wool Insulation	Stone wool (mineral wool) insulation without facing	Adding or increasing insulation (Wall), Adding or increasing insulation (Floor), Adding or increasing insulation (Roof)
Rigid Foam HFC Insulation (PUR or PIR)	Polyisocyanurate (PIR) insulation panel, faced, FIBROPIR	Adding or increasing insulation (Wall), Adding or increasing insulation (Floor), Adding or increasing insulation (Roof)
Rigid Foam HFC Insulation (PUR or PIR)	PUR insulation board, unfaced	Adding or increasing insulation (Wall), Adding or increasing insulation (Floor), Adding or increasing insulation (Roof)
Rigid Foam HFC Insulation, non-gas-permeable coating (PUR or PIR)	PIR insulation boards, aluminum composite foil faced, Eco-Protect Plus	Adding or increasing insulation (Wall), Adding or increasing insulation (Floor), Adding or increasing insulation (Roof)
Rigid Foam HFC Insulation, non-gas-permeable coating (PUR or PIR)	swissporPIR Alu	Adding or increasing insulation (Wall), Adding or increasing insulation (Floor), Adding or increasing insulation (Roof)
Heat pump, ground source (brine-water), vertical	Brine/water heat pump for tertiary building	Installation/Replacement of heat pumps
Heat pump, ground source (brine-water), vertical	Electric heat pump (brine-water, geothermal probe)	Installation/Replacement of heat pumps
Heat pump, water source (water-water), vertical	Water/water heat pump EWSAX06D9W	Installation/Replacement of heat pumps
Heat pump, water source (water-water), vertical	Water heat pump, external, ARWB140LAS4	Installation/Replacement of heat pumps
Heat pump, air source (air-air), multisplit	Reversible air/air heat pump, PUZ-M100YKA2 / PLA-M100EA2	Installation/Replacement of heat pumps

Heat pump, air source (air-air), multisplit	Reversible air/air heat pump, DJ70PHAE+RAC-DJ70PHAE	Installation/Replacement of heat pumps
Heat pump, air source (air-water), combi (DHW + heating + cooling)	Reversible air/water heat pump, PUZ-SWM100VAA + ERSD-VM6D	Installation/Replacement of heat pumps
Heat pump, air source (air-water), combi (DHW + heating + cooling)	Air/water heat pump	Installation/Replacement of heat pumps
Electric convector radiator	Electric radiator	Installation/Replacement of electric radiators
Electric convector radiator	Electric radiator M145112	Installation/Replacement of electric radiators
Electric radiant infrared panel	Electrical infrared radiant heating panel, ECOSUN 600 U/U+	Installation/Replacement of electric radiators
Electric radiant infrared panel	Radiant heating and cooling ceiling panel, ItuAlu	Installation/Replacement of electric radiators
Gas Boiler	Individual wall-mounted gas condensing boiler, MPX2 24 COMPACT	Installation or replacement of a boiler
Gas Boiler	Hybrid boiler (condensation gas + PAC)	Installation or replacement of a boiler
Oil condensing Boiler	Oil low temperature boiler, floor unit	Installation or replacement of a boiler
Oil condensing Boiler	Oil fired boiler	Installation or replacement of a boiler
Pellet (biomass) Boiler	Biomass boiler, for individual use	Installation or replacement of a boiler
Pellet (biomass) Boiler	Woodchip boiler	Installation or replacement of a boiler
Building Integrated PV glass, facade	Crystalline silicone based photovoltaic glass, 0.75x0.75 m, Onyx SolarÂ® G/GM01688A	Installation of photovoltaic panels
Building Integrated PV glass, facade	Building integrated monocrystalline photovoltaic facade cladding (BIPV), per m2, height: 350-3600 mm, width: 350-2000 mm, 140.35 Wp/m2	Installation of photovoltaic panels
Building Integrated PV glass, facade	Photovoltaic module (PV), monocrystalline silicon, 1000 x 1650 x 11 mm	Installation of photovoltaic panels
PV Panel, roof	Roof integrated mono-crystalline photovoltaic module, per m2, 25 kg/panel, 1.95 m2/panel, Clearline fusion PV16-405-M10	Installation of photovoltaic panels
PV Panel, roof	Photovoltaic (BIPV) module, mono c-Si, Wp=130 W, ERS-0191 (130W)	Installation of photovoltaic panels
Metalic Frame	Aluminium frame window, triple glazed, 1.23m x1.48m, E75	Installation of window frame
Metalic Frame	Window system, double glazed with aluminium frame, 1.23 m x 1.48 m, ST60	Installation of window frame
Wood, high density Frame	Wooden frame windows, double glazed	Installation of window frame
Wood, high density Frame	Triple-glazed hardwood frame window	Installation of window frame
PVC (two cavities) Frame	PVC frame window, 76 mm, 1.23x1.48 m, MD Xtrem	Installation of window frame
PVC (two cavities) Frame	Single-sash tilt and turn window with insulated double glazing and PVC-U frame, 1.23 m x 1.48 m, 4 / 16 / 4 mm	Installation of window frame
Glazing, Double-glazing, Normal Glass (E=0.89)	Insulating glass unit, double glazed, 23.88 mm	Installation of window glass
Glazing, Double-glazing, Normal Glass (E=0.89)	Window glazing, single-chamber glass and L-type frame, 1000mm x 1500mm	Installation of window glass
1 Normal Glass + 1 Low Emissivity Glass (0.1 > E > 0.03)	Insulating Glass Unit (IGU), fire-resistant, double glazed, CF60 (5/4/4/5) / 16 Argon / 4 Toughened, 47 mm	Installation of window glass
1 Normal Glass + 1 Low Emissivity Glass (0.1 > E > 0.03)	High performance double glazing, 2x4mm magnetron coated glass, 16mm Alu spacer, air/argon/crypton, CLIMAPLUS 4-16-4	Installation of window glass
Glass, Normal, Laminar (E=0.89)	Insulating glass with laminated on both sides, double glazed, 37.5 mm, Rglass PROTECTHERM 55.2+55.2	Installation of window glass
Glass, Normal, Laminar (E=0.89)	Insulated glass unit from laminated safety glass, fire-resistant, 60 mm, LT 70 %, RLE 17 %, SF 0.56, CONTRAFLAM 120-6 (5/4/4/5)	Installation of window glass

8. References

PRAGMA & CIRCE. (2024). D4.3 – CHRONICLE tool suite for WLC assessment and climate neutral building renovation planning: 1st revision. *CHRONICLE Project (GA 10106972)*.

Hypertech, AEM, R2I, QUE, Ocuallann, KTU, CIRCE, PRAGMA, Neogrid, Zaragoza Vivienda, RINA-C, SIN, EGC, FællesBo, Mytilineos, & IES-RD. (2024). D2.1 – CHRONICLE Business requirements, Use cases & System architecture. *CHRONICLE Project (GA 10106972)*.

IES RD, Hypertech, KTU & CIRCE. (2024). D2.2 – CHRONICLE dynamic Level(s) approach for building and LC performance assessment. *CHRONICLE Project (GA 10106972)*.

QUE. (2025). D2.2 – CHRONICLE Data Model and Common Data Environment. *CHRONICLE Project (GA 10106972)*.

Additional resources:

Bbsr, Ö. I. (n.d.). ÖKOBAUDAT. ÖKOBAU.DAT Im BBSR. [<https://www.oekobaudat.de/en.html>]

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