Security level: RINA/CL/SENSITIVE

Ref. Ares(2022)327372 - 17/01/2022

Accelerating Energy renovation solution for Zero Energy buildings and Neighborhoods

D2.5 Guidelines for supporting the renovation process

Version number: 0.1
Dissemination Level: Confidential
Lead Partner: Rina Consulting S.p.A.
Due date: 31/01/2022
Type of deliverable: Public

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 768718

D2.5 Guidelines for supporting the renovation process

Published in the framework of:

RenoZEB - Accelerating Energy renovation solution for Zero Energy buildings and Neighborhoods

RenoZEB website: www.renozeb.eu

Authors:

Enrico Scoditti– RINA-C

Zafer Ozturk - Salford University

Asier Mediavilla – TECNALIA

Michele Vavallo - SOLINTEL

Revision and history chart:

VERSION	DATE	EDITORS	COMMENT
0.1	15/10/2020	Enrico Scoditti (RINA-C)	ToC issued to partners
0.2	15/05/2021	Enrico Scoditti (RINA-C)	Updated Table of Contents
0.3	15/07/2021	Enrico Scoditti (RINA-C)	Integrations
0.4	05/09/2021	Asier Mediavilla (TECNALIA)	Contribution to Chapter 5, about the RenoZEB Dashboard
0.5	25/09/2021	Zafer OzturK (USAL)	Contribution to Chapter 5, about the Knowledge Based Engine (KBE)
0.6	15/11/2021	Enrico Scoditti (RINA-C)	Integrations
0.7	17/12/2021	Michele Vavallo (SOLINTEL)	Integrations and review
0.8	13/01/2022	Ane Ferreiro (CYPE)	Review
1.0	17/01/2022	Enrico Scoditti (RINA-C)	Last Version

Disclaimer:

The project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 680517.

Table of content

List of figures

1 Executive summary

This deliverable describes the guidelines for supporting the decision-making stages of the whole renovation process for residential buildings.

The guidelines, built on the RenoZEB Concept, aim to assist designers in choosing the optimal scenario and therefore focus mainly on the use, during the design phases, of the tools developed in order to support the decision-making process, namely:

- **RenoZEB Dashboard**, where stakeholders manage and share information along the life cycle process of the renovation
- **Modelling and simulation tools provided by CYPE**, integrated with a configurator purposely developed to facilitate the application of the plug-and-play façade system
- **Knowledge Based Engine (KBE)** which, providing location-based knowledge, supports the decision-making

The report is structured in the following 3 parts:

- Chapter 0 presents a brief description of the plug-and-play modular façade system for deep renovations of existing buildings, which is the core of the RenoZEB project.
- In Chapter 5 the already mentioned tools developed to assist the decision-making process are described.
- Finally, Chapter 6 describes the guidelines for designing with the RenoZEB façade system, focusing mainly on the new elements introduced by the project.

2 Objectives of the report

This report is part of the Work Package 2 and it refers to activities conducted in Task 2.8. The purpose of this report is the definition of guidelines for supporting the decision-making stages of the renovation process for residential buildings.

These guidelines, based on the previous tasks, aim to guide designers and builders through the different design phases to the definition of the renovation project, chosen as the optimal scenario, which best meets the client's needs.

They then focus on the planning and design phases, explaining in detail how Professionals should use procedures and tools developed in RenoZEB in order to implement deep renovation in a holistic, cost-effective and fast way.

3 Definitions

This chapter provides a brief description of the acronyms that will be referred to in the following chapters, whose meaning is therefore essential for a clear and easy comprehension of the present guidelines.

BIM	There are several possible definitions for Building Information Modelling. Among others, according to the Royal Institute of British Architects (RIBA), Building Information Modelling is digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition
IFC	IFC is short for International Foundation Class and files using the IFC file format are Building Information Modelling (BIM) files. Differently from other BIM file formats, IFC files are platform neutral and can be read and edited by any BIM software. The idea behind IFC is to enable interoperability between BIM software, thus promoting collaboration within the Architecture, Engineering, and Construction (AEC) industry
API	API is the acronym for Application Programming Interface, which is a software intermediary that allows two applications to talk to each other
KPI	KPI, or a key performance indicator, are measurable values used to evaluate how successful a design solution (in this context) is at reaching a targe
nZEB renovations	According to the EPBD (Energy Performance of Buildings Directive), a "nearly zero-energy building" (nZEB) means a building that has a very high energy performance and the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. By nZEB renovations are intended those interventions that enable the existing building to become nZEB following renovation. However, the nZEB definition has different nuances from country to country
EPC	EPC stands for energy performance certificate. As defined by the EPBD, the Energy Performance Certificate is a document recognized by a member State which indicates the energy performance of a building or building unit. In addition, following the EPBD, an EPC shall include recommendations for the cost-optimal or cost-effective improvements of the energy performance of a building or building unit. Within the national context, it is up to the Member States to decide on the performance rating of the representation as well as the type of recommendations.
HVAC	The acronym HVAC stands for heating, ventilation and air conditioning, and it's the broadly used term to describe equipment used to keep homes at a comfortable temperature.

4 RenoZEB plug and play façade System

The building envelope retrofit system developed within RenoZEB is an industrialized modular facade system with insulation properties. It is designed to incorporate ventilation, solar thermal and photovoltaic systems, so as to achieve, through the combined impact of each individual component, high energy performances.

The "plug and play" modular façade overlaps the existing building without removing its original envelope and performs the following functions:

- addition of insulation,
- improvement of envelope airtightness,
- replacement of windows and
- the integration of solar systems and efficient ventilation systems

Compared to other modular solution, the key advantage of this system lies in its ability to correct and absorb irregularities in the existing façade (Figure 1).

Figure 1 – System's anchorage design, with possibly of adjustment both in the "x" and "y" axis

The modules are designed to be hung from brackets that must be installed in the façade beforehand. The anchoring system creates a rather deep gap between the existing façade and the modules, which can accommodate ducts, additional insulation and above all compensate for irregularities in the façade. In addition,

adjustments along the three axes (*x*, *y* and *z*) are possible, allowing a certain degree of tolerance to compensate possible design imprecisions.

The modules are connected to each other by a single "plug and play" system, which connects them with two simple movements. Panels are positioned vertically until they are properly hung from the anchor bracket, and then displaced horizontally to its final position (see Figure 2 -Left side).

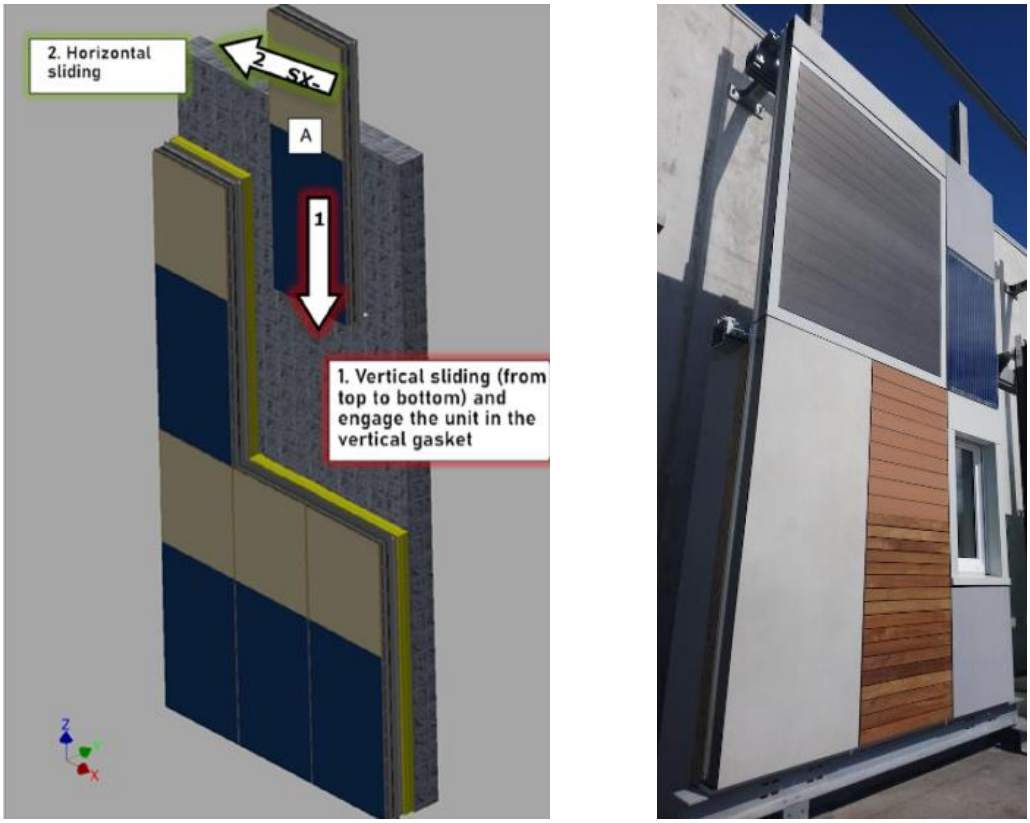

Figure 2 - Connection between panels (On the left) and different finishes and systems of the plug and play façade module (right-hand side)

Finally, the external finish can be customized so that active systems such as photovoltaic, solar thermal or other HVAC components can be integrated. With regards to non-active cladding systems, materials such as fiber-cement, aqua panel, ceramic tiles and timber can be used. Figure 2 (Right side) gives an idea of the possible finishing solutions that can be adopted for the façade module.

5 RenoZEB innovative tools

This chapter provides a concise presentation of the tools developed with the aim of supporting the stakeholders involved in the renovation process, on the one hand, in their decision making and, on the other hand, in the management and the sharing of information. In summary they are:

- **RenoZEB Dashboard,** where stakeholders manage and share information along the life cycle process of the renovation
- **Modelling and simulation tools provided by CYPE**, integrated with a configurator purposely developed to facilitate the application of the plug-and-play façade system
- **Knowledge Based Engine (KBE)** which, providing location-based knowledge, supports the decision-making process at early stages of nZEB renovations

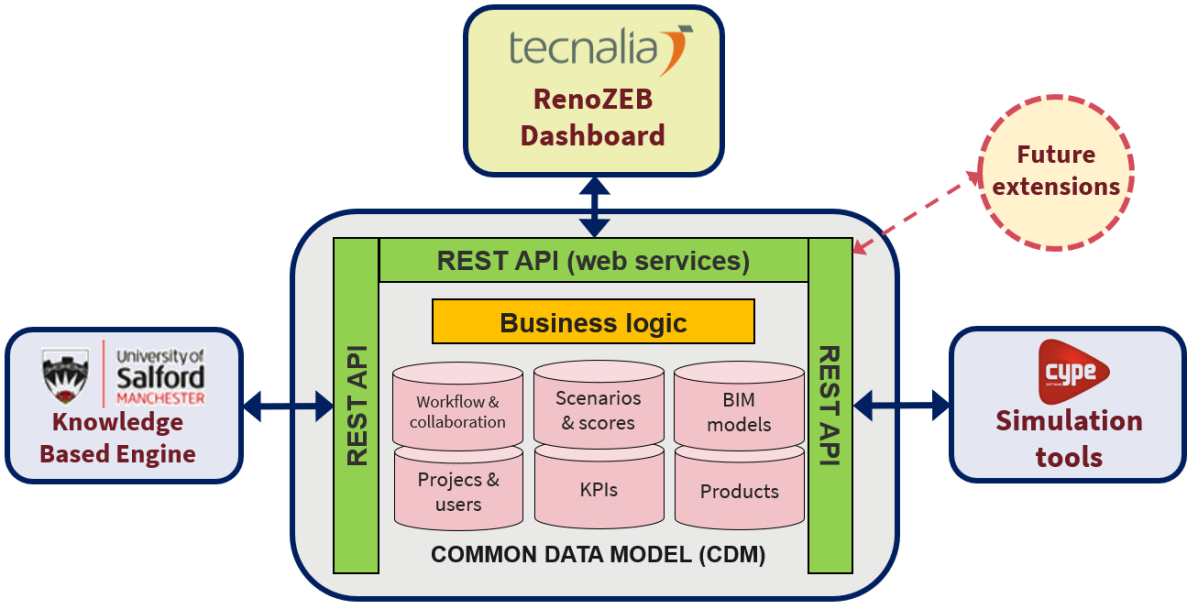

Figure 3 - RenoZEB platform connection with other software tools

Paragraphs 6.1 and 6.2 describe how these tools fit into the workflow defined for RenoZEB and how they should be used.

5.1 RenoZEB Dashboard

The RenoZEB Collaboration Platform is a cloud collaborative environment where stakeholders manage and share information along the life cycle process of the renovation. All the information is structured according to the methodology and phases defined in the project but can be adapted to any project needs. It tries to give response to one of the main problems in collaborative and complex projects which is the inefficient management of information and decision-making and how to involve stakeholders of different roles, including the final client, which leads to not have a shared view of the project objectives and problems.

One of the key aspects is that it is "Open BIM centred", i.e. it allows to upload, share and visualize IFC models, attach information to them and integrate in the workflow external tools which make use of these models for analysis and simulation. The platform supports the workflow defined by the RenoZEB methodology.

One of the most relevant features is the ability to filter and query models and the ability to generate thematic views according to a property value or any KPI

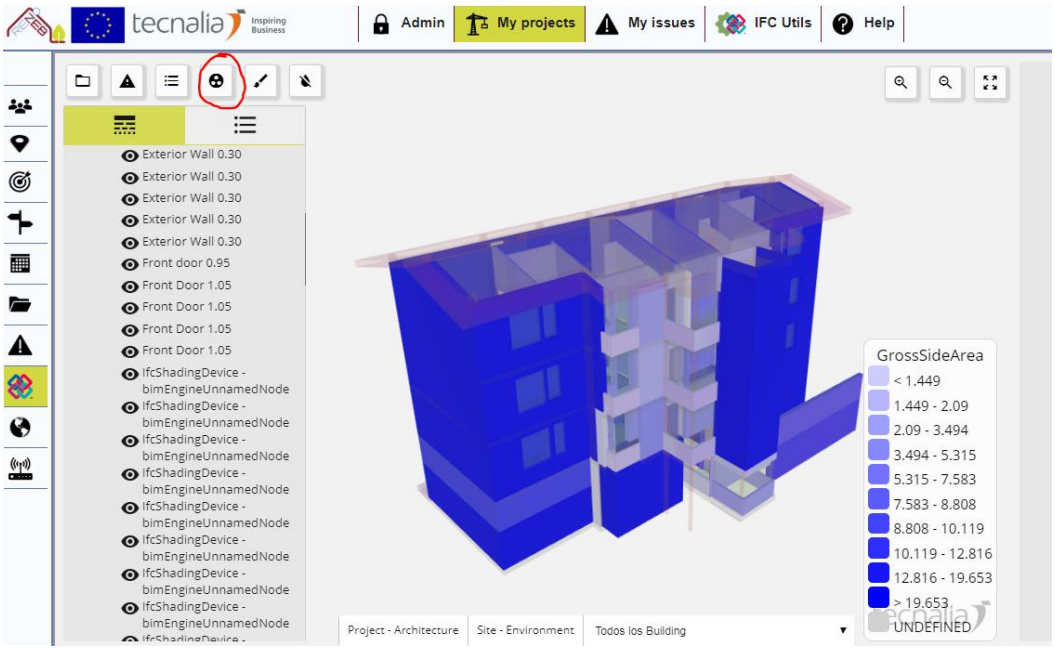

Figure 4. Generating thematic coloured views in the BIM model

Another important feature for the decision-making is the possibility to manage a flexible list of KPIs (economic, energetic or social, among others). The project manager can select the appropriate KPIs for each project and define the target values, as well as their relevance or weight. Therefore, by defining different scenarios and by evaluation each KPI for each scenario a ranking of the scenarios is calculated, identifying the most beneficial scenarios.

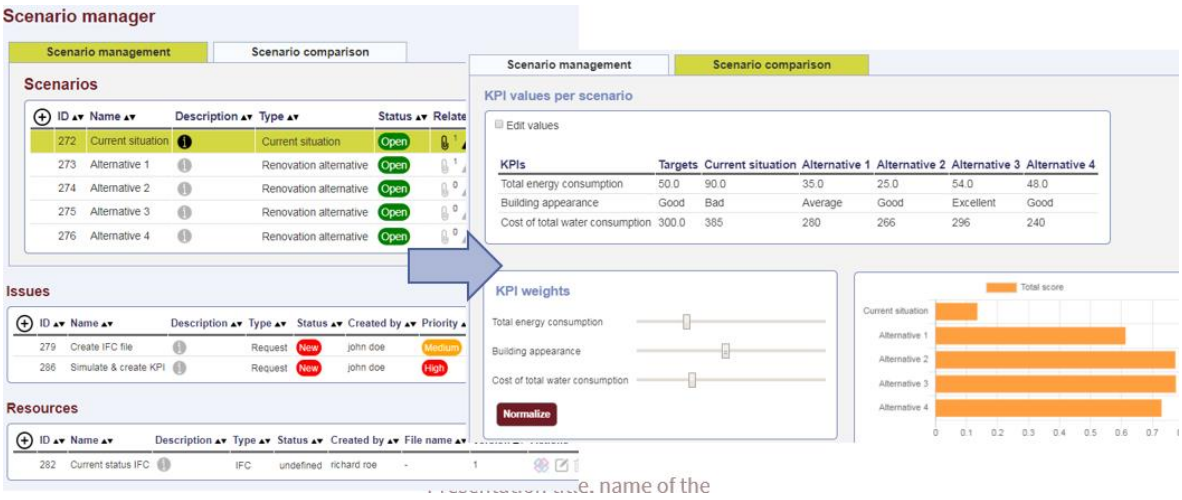

Figure 5. Management of scenarios and resources (left) and ranking and comparison of scenarios (right)

Finally, the platform not only allows the collaboration of end-users through a main graphical user interface or dashboard, but it also allows that external software tools collaborate by automatically exchanging information. For this purpose, a web-service based API has been developed for accessing all the platform functionalities (file upload/download, project management, queries…). Client tools can implement this API (for example, through a plugin) for connecting to the platform.

5.2 CYPE Simulation tools

The working approach of RenoZEB follows the workflow defined by CYPE, the OpenBIM workflow, which is integrated here with the RenoZEB dashboard. The CYPE workflow is based on three components:

1. The BIM (Building Information Model) modelling tool, IFC Builder, also able to import the point cloud from the survey, thus allowing the BIM representation of the survey within the software. The tool is compatible with REVIT from which it can import already created BIM models
2. The specific software tools. Of these, in the context of RenoZEB, one of greatest interest is CYPETHERM, which is needed to carry out energy simulations, and Arquimedes for the management of the construction site.

The BIMserver.center online platform that enables the exchange of information between different software, allowing users to always work on the most up-to-date model versions.

The workflow foresees that the BIM models are defined through IFC Builder, then imported, through the platform, into the different specific programs to perform the relevant simulations.

In addition to the above-mentioned tools, already available from CYPE, specific solutions were developed during the project to facilitate the decision-making process of the user who intends to retrofit the building with the RenoZEB façade system. Specifically:

1. **Open BIM RenoZEB – Focchi Facades**. It is a configurator to design and analyze the RenoZEB solutions. It allows you to import a BIM model of an existing building previously executed with a software developed for this purpose (REVIT, IFC Builder, etc.), and then apply the modules produced by Focchi directly on the facades of the imported model, thus making it possible to obtain the list of elements to be produced accompanied by the precise size of the modules.
2. **E-Catalogue for RenoZEB solutions**. This is a catalogue of all configurable façade modules, already equipped with all the elements that can be implemented (PV panels, solar collectors..), containing all the information needed to carry out energy analyses and costs per m² of the different modules.

Once the model has been created using Open BIM RenoZEB - Focchi Facades, it can be imported into CYPETHERM, which recognizes the RenoZEB facade modules and automatically applies the correct transmittances and other information required for energy analyses. Finally, the software has a plug-in that enables it to

communicate with the RenoZEB dashboard, and therefore to open and save files directly from/on the platform.

5.2.1 Open BIM RenoZEB – Focchi Facades

Open BIM RenoZEB - Focchi Facades is a free application designed to make the layout of Focchi facade panels for building renovation. The program is integrated in the Open BIM workflow, which allows the implementation of the "plug and play" constructive solutions in any BIM model of an existing building, allowing therefore the industrial solution to be part of the collaborative, multidisciplinary and multi-user workflow provided by the technology Open BIM.

Within the decision-making process, the application has a twofold purpose:

- On one hand, to place "plug and play" Focchi panels in a BIM model, drawn it in 3D and exchange information with CYPETHERM suite to be able to perform an energy analysis;
- On the other hand, to obtain a list with the account and the specific size and cost of each panel that is needed in the facade, which will allow the company Focchi to manufacture the necessary panels in the correct size.

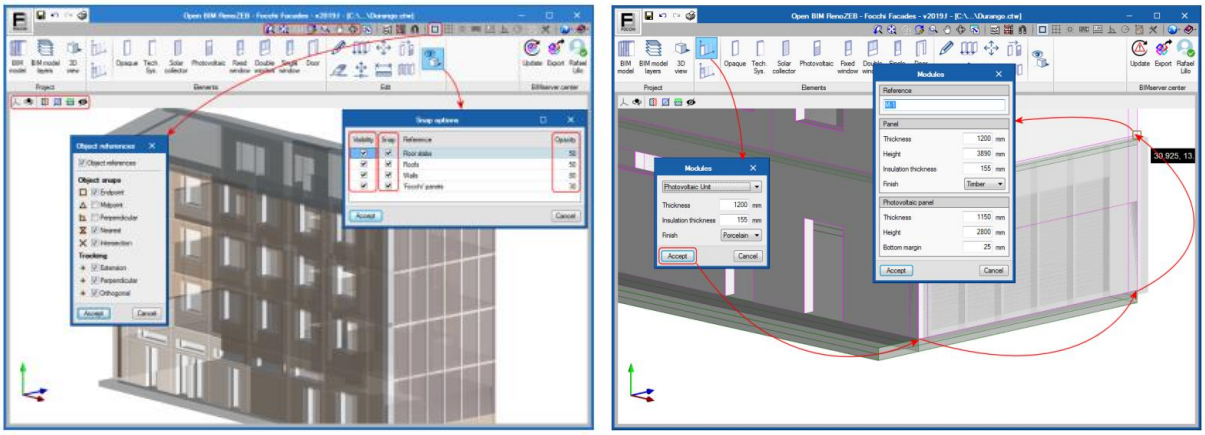

Figure 6 – Open BIM RenoZEB. Focchi Facades working environment options (on the left) and assisted introduction of Opaque Units (on the right)

The program is available for download in

https://bimserver.center/en/store/open_bim_renozeb_-_focchi_facades

Figure 7 - Open BIM RenoZEB – Focchi Façade Splash

5.2.1 Renozeb E-catalogue

The RenoZEB E-catalogue is an innovative data repository for Net Zero Energy Building solutions. The deep renovation solutions have been defined according to the most relevant variables characterizing energy refurbishment interventions, such as: building typology (residential), geo-cluster solutions (Mediterranean, Oceanic and Continental) and identification of problems (building envelope, HVAC systems, apertures...). RenoZEB E-catalogue has been introduced in CYPETHERM tool and has an extension in RenoZEB Dashboard. Both catalogues will be interconnected by ID names and will be accessible from both the web and software tools. RenoZEB E-catalogue has all the necessary data to make the simulation in CYPE software tools, meanwhile the RenoZEB platform catalogue will allow the user to create a filtering to choose among the best solutions for their building. The solutions of the E-catalogue have been chosen among the most cost effective wide extensive solutions available in EU market making easier to find them anywhere around EU territory. Types of solutions had been defined in relation with the main problems concerning the deterioration of envelopes and HVAC systems. Final solutions are: constructive (roof, facade, floor), aperture (windows) HVAC systems (heating and cooling, ventilation) and PV panels (for electricity generation).

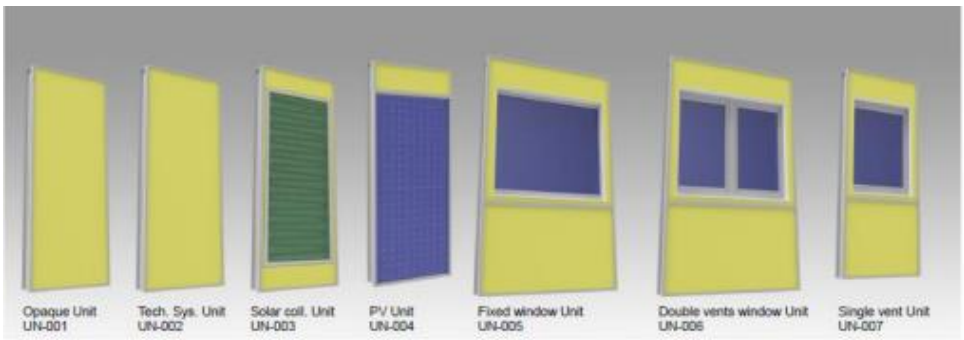

Figure 8 - Plug and Play types of panels

5.3 Knowledge-Based tool for supporting the decision-making process of RenoZEB

A knowledge base is a centralized repository where information is stored, organized, and then shared. In this respect, RenoZEB KBE Tool is a service that:

- Stores EU-wide Climate data and Building level Energy Performance data from multiple sources,
- Processes and refines the abovementioned data geo-spatially,
- Generates and shares knowledge regarding property's location-specific energy requirements and a local comparison with other dwellings in the area as well as a rough estimation of property value increase in return of an energy upgrade.

RenoZEB KBE tool focuses on knowledge retrieval from climate and EPC data to maintain a better understanding of the interaction between local environmental conditions and the property-specific energy performance at abstract level and features a comparison with similar buildings in the area.

KBE mainly targets providing support to decision making process at early stages of nZEB renovations. From RenoZEB concept perspective, the scope of KBE is within the "Plan Phase" of DR Lifecycle.

RenoZEB KBE tool provides location-based knowledge in the following domains:

- ✓ Local Climate Data (Temperature min/max/average values)
- ✓ Heating and Cooling Degree Days to understand location specific heating and cooling loads
- ✓ Address-based reconfigured Energy Performance Certificate (EPC) for the selected property (EPC label and Score)
- ✓ EPC average value (Both the EPC Label and Score) and number of properties for the similar built-type dwellings in the selected post code area and/or city
- ✓ If renovation leading to an upgrade of one step in EPC Label, the number of properties with Higher EPC
- ✓ Location (country) based approximate increase in the property value due to energy-retrofit (EPC upgrade)
- ✓ Area 3D Buildings viewing

RenoZEB KBE can be used either as a stand-alone tool or it can be used in coordination with RenoZEB Platform.

6 RenoZEB Guidelines

This chapter is dedicated to the description of the guidelines during those phases leading to the choice of the optimal scenario, i.e. the Plan phase and the Design phase, which are addressed in detail in the following homonymous sections.

The guidelines are defined on the basis of the methodological steps developed during the project and described in Deliverables 2.2 and 2.3, specifying when and how the decision support tools described in the previous chapter are to be used.

Figure 9 presents the RenoZEB concept as a holistic approach to deep Renovation, highlighting the significative parts for the scope of this guidelines. In this process, the RenoZEB Dashboard could be used already during the Plan phase, but it becomes essential during the Design phase to allow comparison between different scenarios, as well as for CYPE modelling and simulation tools.

The KBE platform, on the other hand, is a tool designed for the initial planning phase, while the quantitative estimation of the property value increase is undertaken in the context of the economic analyses that follow the definition of the scenarios.

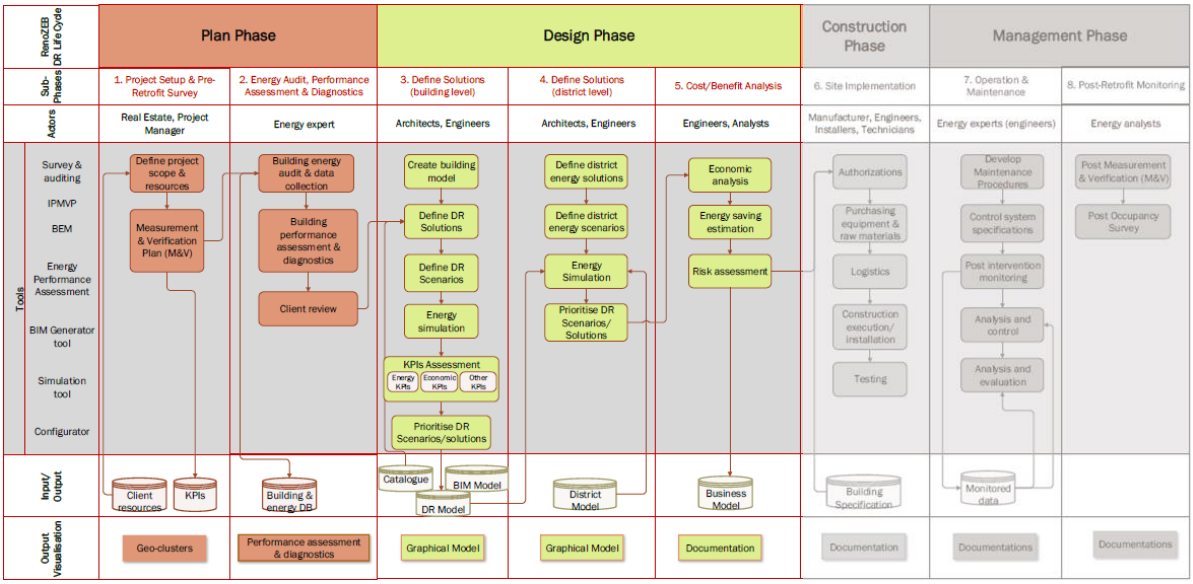

Figure 9 - RenoZEB concept[1]

[1] RENOZEB: Deliverable 2.2. Definition of the RenoZEB concept and process. pp. 24

6.1 Plan Phase

This section describes the procedure to be followed during the initial plan phases of deep renovation projects involving the RenoZEB façade system. Once assessed whether the buildings under investigation can be renovated through the implementation of the RenoZEB façade system, the steps to be taken to assess the technical and economic feasibility of deep renovation interventions will be analyzed, focusing mainly on the aspects related to the facades.

The primary purpose of this phase is to establish whether, on a preliminary basis, the renovation through a RenoZEB façade system is:

- technically feasible and
- potentially cost-effective,

thus, providing all the relevant indications of the requalification intervention to guarantee, in advance, the compliance with the environmental and urban regulations, the respect of the hydrogeological and seismic constraints, the energy efficiency.

This phase results in the definition of a design at concept level that can be subsequently declined into different scenarios to be analyzed and compared in the following phase.

In detail, the activities to be carried out in this phase concern:

- The analysis of objectives to be agreed with the client
- Evaluation of the compatibility of RenoZEB plug and play system with the building
- Preliminary cost-effectiveness assessment
- The analysis of technical and regulatory constraints and requirements
- The execution of the site investigation and survey, including BIM representation of the existing building.
- The execution of an energy audit of the existing building.
- The identification of the concept

At this stage, the use of the RenoZEB Dashboard is limited to the creation of the project, the definition of KPIs, and the exchange of shared information including, possibly, the point cloud and surveys.

The activities with the most peculiar aspects related to RenoZEB are discussed below.

6.1.1 Evaluation of building compatibility with RenoZEB plug and play system

The first step when approaching a deep renovation with RenoZEB is to assess whether the building is suitable for the implementation of an industrialized façade system.

The ideal target of RenoZEB are residential buildings characterized by (1) concrete structures, (2) a level of thermal insulation inadequate to current standards and, (3) not an excessive degree of complexity of the facades, although the façade module developed by Focchi is also compatible in buildings with overhanging parts and balconies.

Block and Multi Family houses built before the 1980s are therefore the ideal application context for RenoZEB plug and play facade, where the availability of large façade surfaces means that benefits of implementing an industrialized façade system are greater, even if can still be easily adapted to Single and Terraced houses.

Figure 10–Building typologies across Europe (from TABULA project)

In addition, the building must not be subject to excessive historical-architectural constraints preventing the adoption of innovative façade systems.

Narrowing the field of application even further, the buildings potentially eligible for renovation with RenoZEB are those mainly located in urban suburbs, built after the 1950s and characterized by a high level of façade decay.

6.1.2 Pre retrofit survey and goals setting

The objective of this step is twofold. On the one hand, it aims to gain a deeper understanding of the building, while on the other hand, through the discussion with the client, it aims to understand the client's wishes and interpret their objectives by transposing them into measurable KPIs. It therefore involves the execution of the necessary surveys, the gathering of available data (existing bills and 2D drawings) as well as the extrapolation of the point cloud, to be carried out by laser scanner, through which it will be possible to create the BIM model of the existing situation.

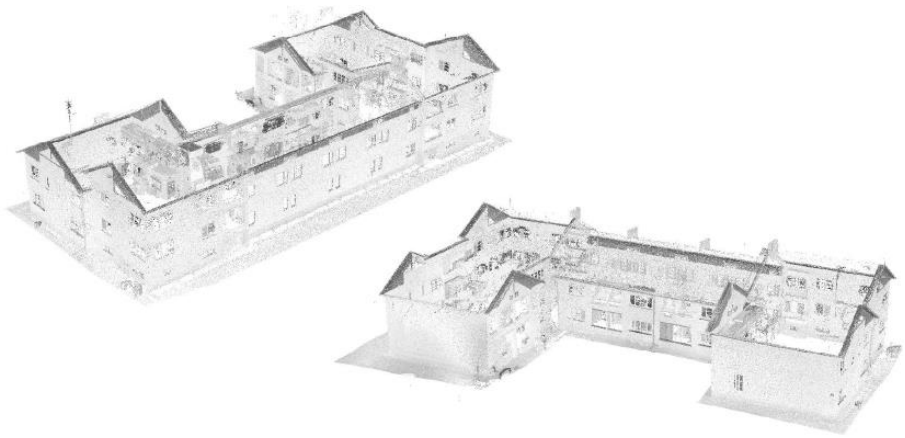

Figure 11 – Voru Demonstrator – Point cloud

On the basis of the information provided by the client, and according to the level of knowledge of the building acquired through the surveys, it will then be possible to define the KPIs of the project, defining for each of them the rule for their scoring. At this stage it is possible to start using the RenoZEB Dashboard. It is possible to create a new project, define users and roles, upload the available data from the surveys (Point Cloud and 2D drawings) to share them with who will have to create the BIM model of the building. In addition, it is possible to select the previously identified KPIs.

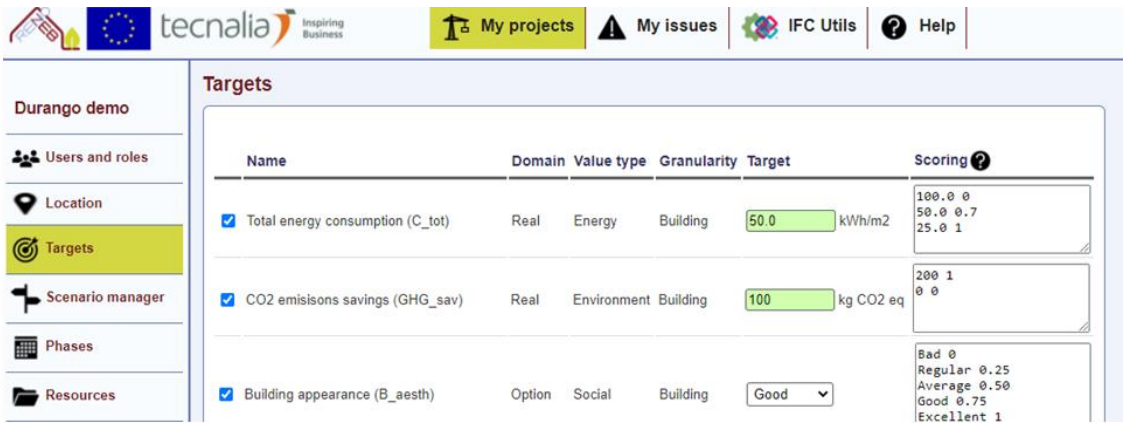

Figure 12 - RenoZEB Dashboard - KPIs definition

6.1.3 Preliminary cost-effectiveness assessment

Compared to a conventional External Wall Insulation, the implementation of an innovative industrial façade renovation system, such as RenoZEB, has several advantages, such as:

- The possibility of integrating the façade with a mechanical ventilation system with heat recovery, resulting in enhanced levels of comfort and air quality
- The opportunity to install photovoltaic panels and solar collectors on the façade, thus maintaining the full accessibility of the roof.
- The minimization of thermal bridges
- Modernization of the aesthetic appearance of the building
- Reduction of maintenance costs
- The slowing down of the building's degradation process

However, for this solution to be economically viable, it needs to produce significant benefits that go beyond energy savings alone, thus resulting in an increase in property value (and therefore of the possible rental yield).

In this respect, factors related to the deterioration of buildings that lead to higher costs and have a greater impact on their real estate value were identified during the project. As a result, it was possible to correlate the problems associated with damages in the envelope or malfunction of the systems with the previously identified factors, thus qualitatively determining a correlation between building elements and the factors which cause loss of property value[2] (Figure 13).

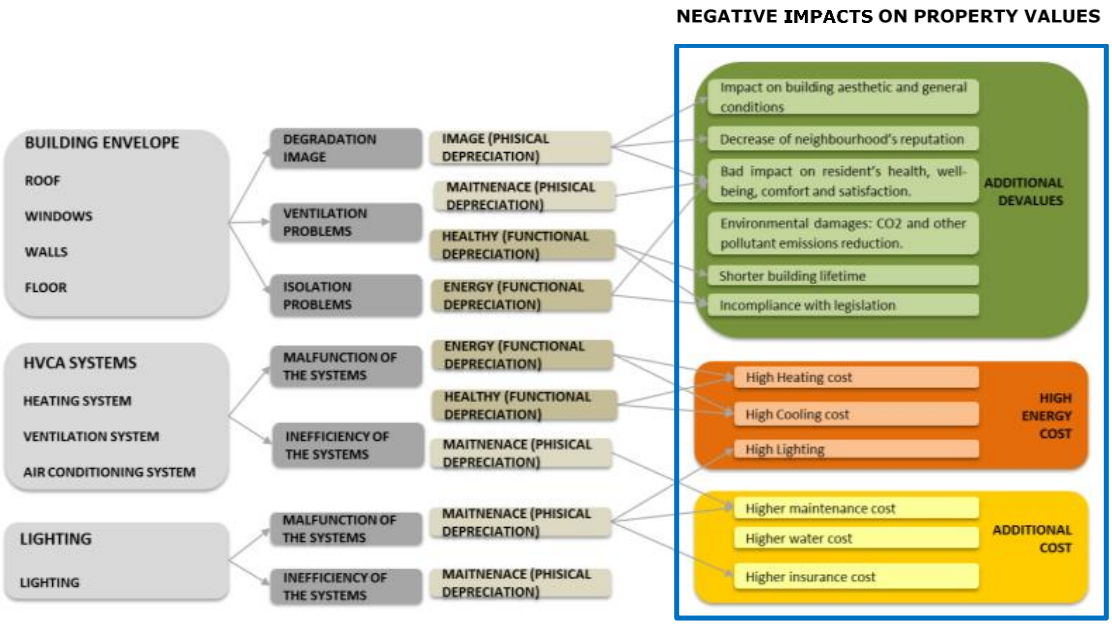

Figure 13 Correlation between building elements and the factors which cause loss of property value

[2] RENOZEB: Deliverable 2.3. Implementation of the RenoZEB concept into the phases of the whole renovation process. Identification of problems associated with the loss of property value. pp. 30

The deterioration of the building is therefore one of the key elements to be considered in the real estate assessment. Property depreciation linked to deterioration can be of two types: functional and physical, as defined below:

- Functional depreciation. It is considered as such housing loss of value due to its defective adaptation to the function to which it was intended for (obsolescence, design, lack of adaptation to its use, etc.).
- Physical depreciation. It is considered the housing loss of value related to its conservation status (in which its age and the duration of its components influence).

These definitions of depreciation, which is generally considered for the whole building, establish a direct relationship with the functional or physical deterioration of each element, through the basic problems that derive from its current situation. The relationship and the increase in value, depends on the initial state of the building. The greater the difference between the baseline and the result from the intervention, the higher the revaluation is.

In line with this approach, the following table details the impact of the various pathologies affecting the facades, indicating for each of these the expected impact on the physical and functional depreciation of the building.

The table[3] (Figure 14) include a qualitative assessment of the property loss as well in a scale of 3 degrees: high, medium or low depreciation.

BUILDING COMPONENTS	CONSTRUCTIVE TIPOLOGY	DAMAGE OR PATHOLOGY	IMPACT OF THE PATHOLOGIES ON BUILDING DEPRECIATION			
			FUNCTIONAL DEPRECIATION		PHYSICAL DEPRECIATION	
			AFFECTING TO ENERGY EFFICIENCY	AFFECTING TO HYGIENE , HEALTH AND ENVIRONMENT	AFFECTING TO IMAGE	AFFECTING TO MAINTENANCE
FACADE	INSUFFICIENT INSULATION	Cracks (involving the whole thickness)	High	Medium	High	High
		Superficial fissures (small thickness cracks that mostly affect the finish)	Low	Low	Medium	Low
		Erosions or spalling of finishing material (painting chipping, rendering flaking, stone alteration... etc.)	Low	Low	Medium	Medium
		Accumulation of dirt (due to deposition or to material dragging by rinsing).	Low	Low	Medium	Medium
		Detachments of the finishing	Medium	Low	High	High
		Efflorescences	Low	Medium	Low	Medium
		Mosses and lichens on the outside face	Low	Low	Medium	Medium
		Moulds due to condensation on the inside face	Medium	High	High	Medium
		Oxidation	Low	Low	Medium	Low
		Corrosion	Medium	Low	High	High

Low influence on the depreciation of the property
Medium influence on the depreciation of the property
High influence on the depreciation of the property

Figure 14 - Categorization of the Functional and Physical depreciation of the property value with regards to main pathologies in façade

The table provides a useful aid to understand, at a preliminary stage, based on the degradation phenomena identified on the façades, whether the RenoZEB renovation work, counteracting these degradation phenomena, will lead to a significant increase in property value.

[3] RENOZEB: Deliverable 2.3. Implementation of the RenoZEB concept into the phases of the whole renovation process. Identification of problems associated with the loss of property value. pp. 39

To complement this approach, the KBE platform, described in paragraph 5.3, makes it possible, at this preliminary stage, to identify the most promising contexts for the application of RenoZEB, focusing only on the increase in property value expected as a result of the improvement of the building's energy performance.
The KBE platform makes it possible to quickly match climate and building stock data, from which it is possible to first identify the most promising contexts for the application of RenoZEB, as well as assessing the percentage increase in property value expected as a result of an increase in energy category across different EU countries.

6.1.4 Identification of the Concept

Once the necessary surveys and diagnoses have been carried out, the customer's objectives have been established, the applicability of RenoZEB has been assessed and the preliminary cost-effectiveness has been evaluated, the solution can be identified at concept level.

The process leading to the preliminary concept definition is rather straightforward and therefore takes place in 4 steps, (already described in deliverable D3.2):

1. **Identification of the existing building to renovate,** where compatibility with RenoZEB's plug and play facade system is assessed
2. **Identification of constraints and requirements.** In this phase all the constraints and the requirements that may affect the design of the façade using the RenoZEB system are identified. These are mainly structural constraints. It is necessary to understand which structural scheme characterizes the existing building (frame or load-bearing walls), whether the existing system is suitable to support the vertical loads induced by the facades, whether the loads of the facades excessively modify the dynamic behavior of the building.

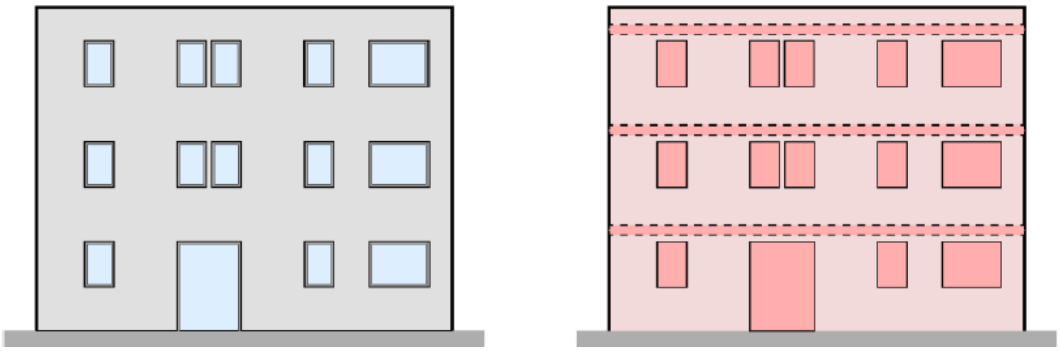

Figure 15 – Identification of the concept Steps 1 and 2

3. **Identification of the baseline.** This phase identifies baselines for the design of new envelopes system of the building. Based on boundary conditions, the concept design uses these elements as guidelines to design the module that will constitute the RenoZEB envelope system.

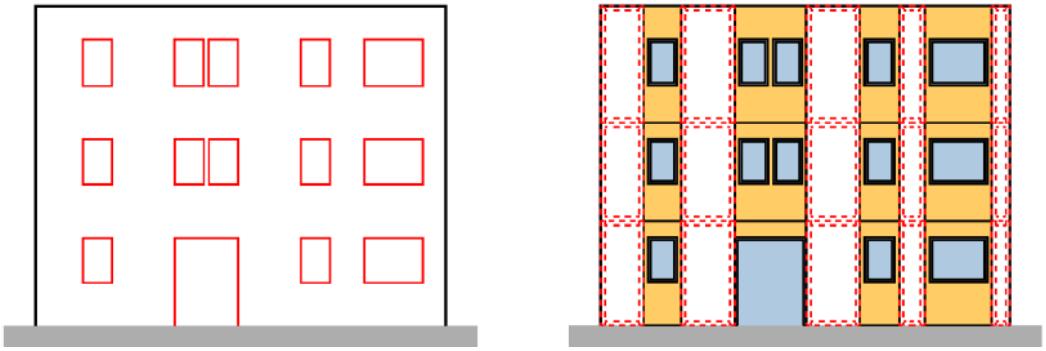

Figure 16 – Identification of the concept Steps 3 and 4a

4. **Modules design.** The first modules to be designed are the one that depend on the elements that will not change during the renovation process. This is the case of modules that need to be designed on the reference of openings (windows, doors). The remaining modules needed to complete the envelope will then be defined. All modules must be consistent with the objectives that emerged from the discussion with the client and the expected KPIs for the renovation project. Furthermore, according to orientation and existing regulatory constraints, these modules may be integrated:
    - Photovoltaic panels
    - Solar collectors
    - Technical system units.

    At this stage both the finish and the different window models to be installed can also be chosen. If necessary, some of the modules can be combined to speed up assembly on site and thus reduce costs. This last step is obviously conditioned by the maximum dimensions that can be transported on a standard truck of 13.6m (L) x 2.4m (W) x 2.6m (H).

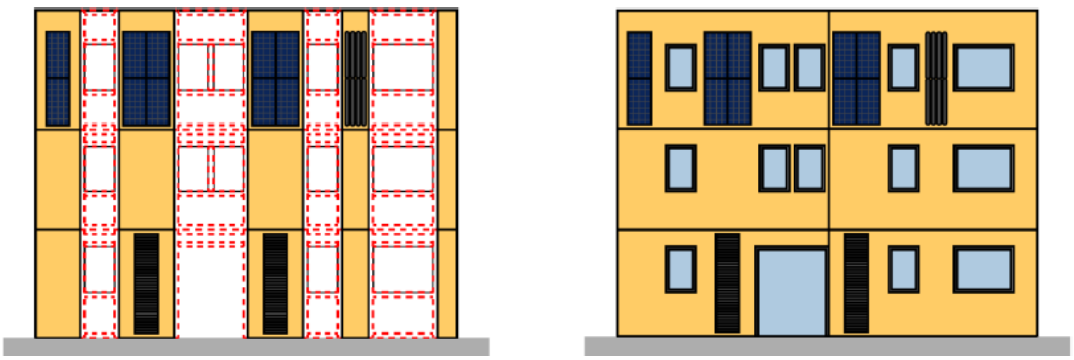

Figure 17 – Identification of the concept Steps 4b and 4c

The following paragraphs discuss the main constraints and requirements for using the RenoZEB façade system.

6.1.4.1 Structural boundaries

Structural system has a central part in the envelope design. Before any preliminary study on the envelope solution to be adopted, it is crucial to have the certification on structural stability and the load capacity of the building subject to renovation.

The realization of a new cladding system that can include different technological components has its own load and it is important to know if the building can bear this weight (up to 600kq per module with dimensions 1200 x 3000 mm). Two levels of problems have to be checked:

- ✓ Local: it must be verified that the single bearing elements are locally able to provide adequate strength and stiffness where the brackets supporting the modules are placed.
- ✓ Global: it must be verified, especially in the case of areas with high seismicity, that the increase in the overall loads of the façade system does not result in an excessive increase in the dynamic forces induced by the earthquake.

If the existing structures are not able to support the façade modules, specific measures must be taken in order not to preclude the possibility of adopting RenoZEB. In the case of areas affected by high seismicity, it may be necessary to provide for structural reinforcement, such as the insertion of walls or bracings, possibly even considering that facades may be supported on separate foundations that are independent from the foundations of the existing building.

Schematically, it is possible to identify two categories of facades (AEE – Institute for Sustainable Technologies, 2010):

- **Façade load on existing structure** – the load capacity of the existing structure is enough to transmit the load of the façade to the foundation. Calculation of foundation capacity should be considered with two possible solutions:
  1. Not reinforced foundation – the existing foundation has the capacity to support the increased load of the new I;
  2. Reinforced foundation – the existing foundation is enlarged to support the increased load of the new façade
- **Self-standing façade** – the load capacity of the existing structure is not enough to transmit the load of the façade. A structure that could support the façade should be designed and realized, unloading on:
  1. Existing foundation – the existing foundation has the capacity to support the load of the new facade;
  2. New foundation – a new foundation for the façade structure is created.

Hereafter (Figure 18) both the case of a self-standing façade on new foundation and of a façade fixed on existing structure are schematically shown.

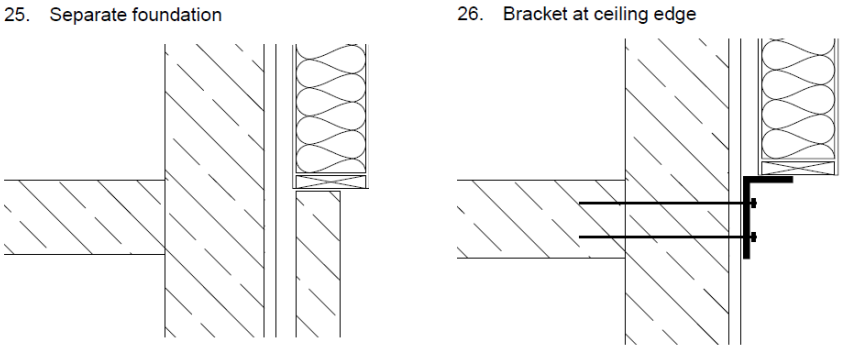

Figure 18 - Self-standing façade on new foundation (on the left) and façade fixed on existing structure (on the right) (Lattke, Larsen, Ott, & Cronhjort, 2011)

Although these aspects are typically resolved in the later design phases, they should already be taken into account at this stage because, otherwise, they can give rise to significant additional structural costs, especially in seismic zones.

6.1.4.2 Technical requirements

Other issues that deserve a deeper analysis already at this preliminary stage concern the regulations in force on the following aspects:

- Fire prevention
- Acoustic insulation
- Energy efficiency

Their analysis is important already at this stage as they may imply constraints able to condition the application of RenoZEB, even precluding the applicability of some elements (e.g. in France the applicability of façade photovoltaics is highly restricted).

- ✓ **Fire prevention** – regulated by European standards only partially, it depends largely on national regulations and technical guideline. The most important aspects for RenoZEB envelope system are:
  - Hazard of fire-growth and smoke spreading along facade modules
  - Hazard of fire-growth and smoke spreading caused by installations, ducts and resulting penetrations of fire-sections.

  To face the fire prevention issue, some measures can be studied:
  - Layout of building (not subject to RenoZEB intervention)
  - Constructional measures (physical structure, materials, etc.)
  - Technical measures (fire detection systems, sprinkler systems, fire dampers, claps, etc.)

- ✓ **Sound insulation** – objective is the prevention of sound transmission between adjoining room, sound from outdoor and sound emission of technical systems installed in façade. This is a necessary aspect to be taken into account especially if the façade system is integrated with mechanical

ventilation systems with heat recovery, potentially having an acoustic impact on the user.

The following measures contribute to improve sound insulation:

- Massive and heavy components
- Air tightness
- Positioning of ducts and fans on the outside of the facades

✓ **Thermal insulation** – the thermal performance is the summa of new envelope solution with the existing façade. The final performances need to be in line with local norms for envelope. Of particular concern is the careful study of condensation and ventilation between old and new façade, that should be subject to specific evaluation.

6.2 Design Phase

This section describes the procedure for applying RenoZEB during the Design Phase.

At this stage, the Plan Phase clearly showed that the application of RenoZEB is feasible, potentially cost-effective and potentially suitable for the targets set by the client. This then leads to the actual design phase, whose overall objective is to develop the final project, identified as the optimal solution among those that can be provided through RenoZEB.

Starting from the concept defined during the previous phase, it is then possible to define the different scenarios to be compared, characterized by different costs, aesthetic and energy results. The solutions developed in the context of RenoZEB to facilitate the decision-making process become essential here:

- The RenoZEB Dashboard, already described in paragraph 5.1
- The configurator to design RenoZEB solutions and the other CYPE tools described in the paragraph 5.2

All the tools mentioned in the previous two points are already applied during the initial planning phase, but it is at this stage that they become essential to support clients and professionals involved in defining scenarios, evaluating and comparing them, and finally in choosing the optimal scenario.

In detail, the activities to be carried out in this phase concern:

- The execution of the BIM model of the existing building on the basis of the available point cloud and plans
- The implementation of the necessary information to be made within CYPETHERM and the subsequent energy analysis
- The set-up of the different scenarios to be carried out through the configurator described in paragraph 5.2.1 (Open BIM RenoZEB - Focchi Facades)
- The selection of the best option by comparing different scenarios using the Dashboard
- The economic analysis with particular regard to the estimation of the property value increase
- The detailed design of the façade, focusing on the different disciplines involved (structural, HVAC, firefighting, etc.) and all the issues that may arise during construction and operation.

The activities with the most peculiar aspects related to RenoZEB are discussed below.

6.2.1 Scenario selection - Use of the tools in the Design Phase

As seen in the previous chapter, the RenoZEB Dashboard can be used as early as the Plan Phase, by creating a new project, loading the available data from the surveys (Point Cloud and 2D drawings), defining users and roles and, above all, selecting the KPIs that are considered relevant for the choice of the best scenario, defining for each of them the rule for their scoring. If the BIM model and the energy diagnosis for the existing situation were already carried out during the previous phase, it would already have been possible to define the "current situation" scenario to which to associate the IFC file of the BIM model and to assign values to the various KPIs.

In this phase, instead, scenarios representing the different RenoZEB renovation alternatives are defined. Recalling briefly what has already been described in chapter 5, the RenoZEB workflow involves firstly the definition of the BIM model of the existing building from the point cloud and the available 2D drawings. Once this BIM model is available, it will be possible to import it into the configurator developed within RenoZEB (the Open BIM RenoZEB - Focchi Facades tool) to implement the façade modules and thus define the different scenarios. As a result, a file for every different scenario must be defined.

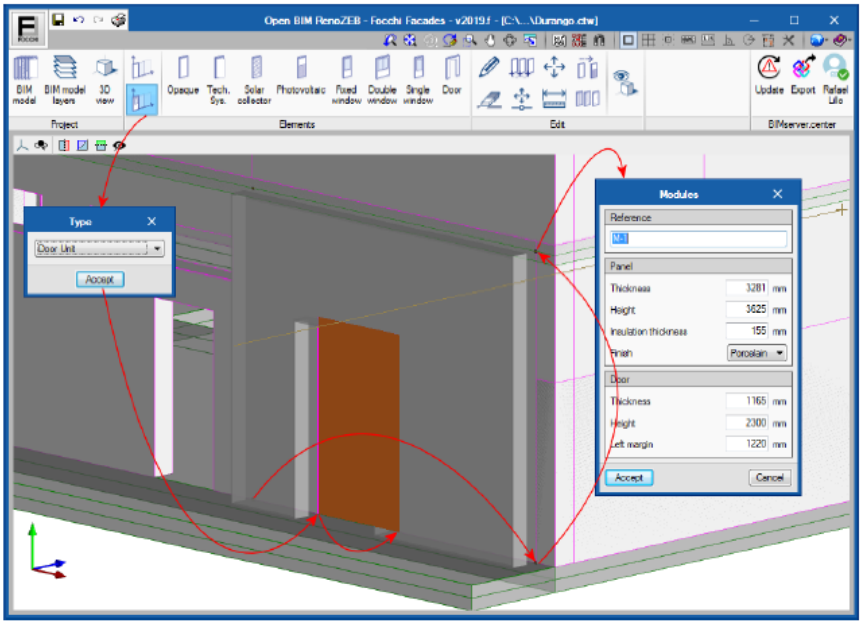

Figure 19 - Open BIM RenoZEB - Focchi Facades tool – Assisted introduction of panels with windows or walls

Following the definition of a scenario through the configurator, the related IFC file must then be imported into CYPETHERM in order to proceed with the energy analyses.

Then, the IFC files of the models can be directly uploaded to the RenoZEB Dashbord and associated with the scenario previously defined on the platform.

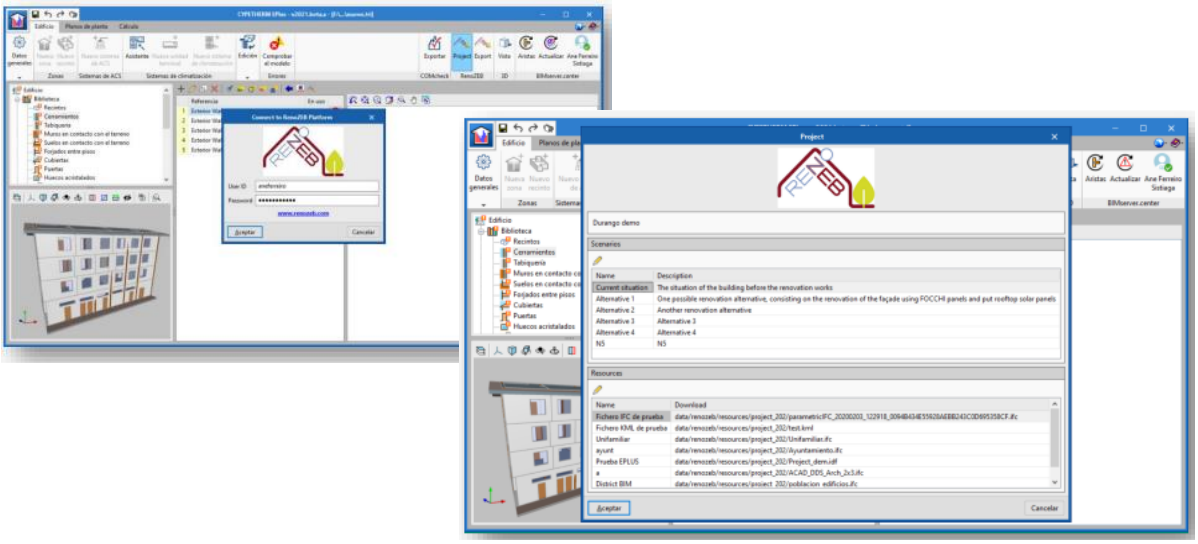

Figure 20 – CYPETHERM: Plug-in to interact with the RenoZEB Dashboard

On the basis of (1) simulation results, (3) 3-dimensional views of IFC files and (3) cost information, it will then be possible to assign values to each KPI of the different scenarios defined in the platform.

Finally, through the "Scenario comparison" form of the "Scenario manager" tab it will then be possible to choose the optimal solution among those defined in the platform (see Figure 21)

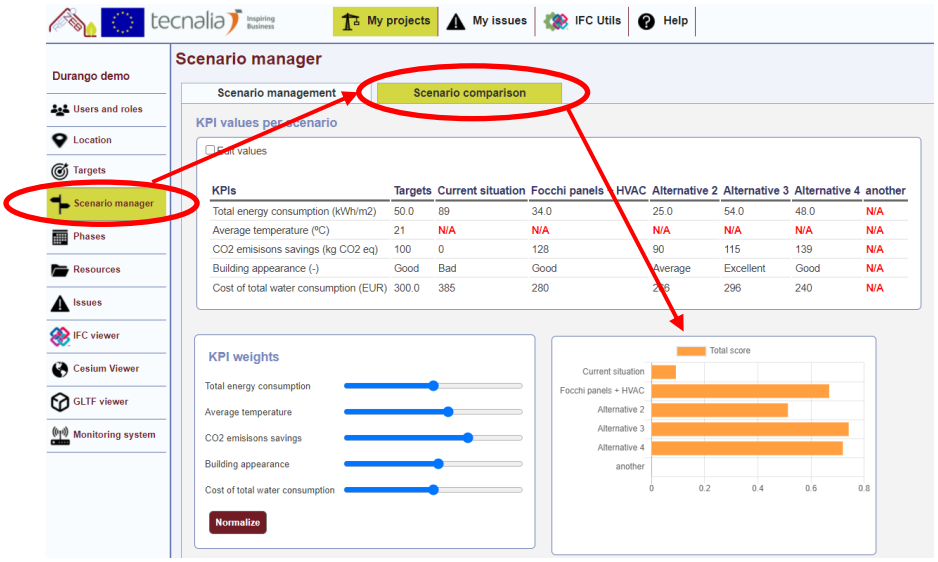

Figure 21 - RenoZEB Dashboard. Comparison between scenarios

6.2.2 Economic analysis and assessment of the increase in Property Value

This section describes the work to be carried out in order to confirm the cost-effectiveness of the chosen scenario and, in general, of the application of the RenoZEB façade system.

During the Plan Phase a preliminary qualitative assessment is carried out through (1) the Knowladge-Based tool (KBE) described in paragraph 0, as well as (2) the analysis of the pathologies affecting the existing building façades, having identified during the project those which cause the greatest depreciation of the building.

As already pointed out, these are valuable tools in the very early planning stages, but they do not provide a definite quantitative indication of the actual increase in property value that can be achieved through RenoZEB. To this end, the approach identified in RenoZEB is to adopt the Hedonic Pricing method.

The hedonic model, through the analysis of the main components affecting house prices levels, makes it possible to determine the implicit price of each characteristic, and therefore the effect on house prices level when a certain characteristic (or feature) varies. Specifically, in RenoZEB the aim is to determine the effect on the property value of the many aspects that are altered through the renovation implementing RenoZEB solutions. Namely:

- The improvement of the energy performance,
- The possible inclusion of mechanical ventilation systems, incorporating ducts in the façade plug&play system,
- The improvement in the maintenance state of the property,
- The general modernization of the building, in terms of aesthetic appeal and building quality,

A study carried out for three major cities in northern Italy (with more than 500,000 inhabitants) estimated that the expected increase in property value following RenoZEB renovation could be as high as 30% of the original value of the building[4].

The analysis was carried out on large cities in order to have a sufficiently large sample of data, obtained through real estate advertisement sites. The analogous analysis conducted for Durango and Voru, although in this case partially affected by the lack of a sufficiently robust data sample, led to similar results[5].

[4] RENOZEB: Deliverable 8.5. Replicability Analysis in virtual demos
[5] RENOZEB: Deliverable 7.5. Monitoring results evaluation and learned lessons through the renovation project execution

By way of example, some of the results obtained for the city of Turin are reported. In particular Figure 22 shows the impact on the logarithm of the price per square meter of the following:

a) ***Construction period***: % measured against the reference period 1970-1990
b) ***State of maintenance****:* % measured against the condition *Acceptable*
c) ***Energy performance***: % measured against the higher Energy class

It can be noted that the premium on the unit price paid for the upgrade from class G to class A is about 20%. The upgrade from an acceptable maintenance condition to an excellent condition (new or newly refurbished) implies an increase in value of 11%. An apartment within a building built in the last 20 years is evaluated on average 17-18% more than a house built in the period 1970-1990.

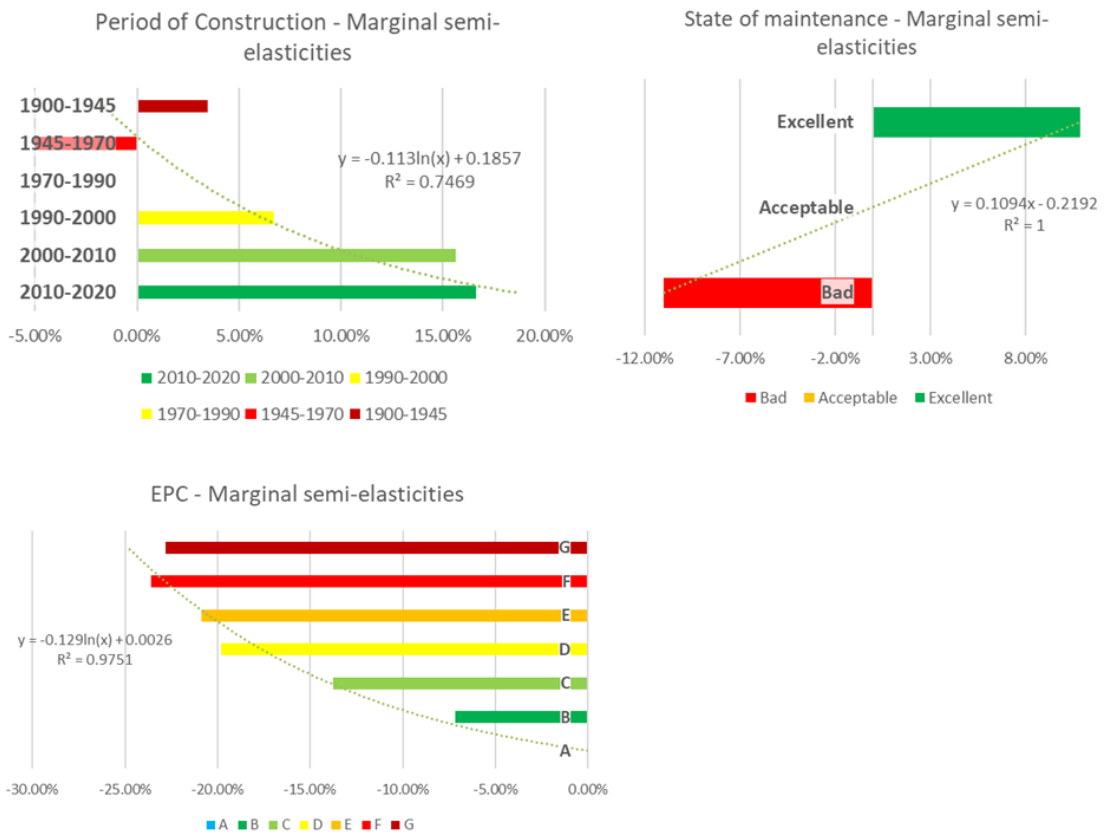

Figure 22 - Application of the hedonic price model for Turin. Results[6]

As with the Durango and Voru demonstrators, the procedure at this point foresees the application of the hedonic price method also for the context under analysis in order to identify, also for this framework, the expected property value increase.

[6] RENOZEB: Deliverable 8.5. Replicability Analysis in virtual demos

6.2.3 Detailed Design of the facade

The final step is the detailed design of the façade, to be carried out in consultation with the system manufacturer. With the help of the configurator and of the BIM model obtained from the point cloud, it is possible to determine the dimensions of the panels and the position of the anchors. The distance between the different anchors depends on the actions they are able to support. For instance, In the case of the Durango Demonstrator, a system with six chemical fixings were used for each anchor. As a result of the calculation, anchors were prescribed at horizontal distances of 1.35 to 1.7 m, depending on the type of panel installed. In all cases, vertical distance was set to be equal to the slab-to-slab height (Torres, et al., 2021)

Figure 23 - Durango demonstrator. Positioning anchorages of façade modules

It is also necessary to define the system engineering layouts, detailing precisely:

- the pipework passages, in particular those related to the ducts for the mechanical ventilation systems, being more voluminous,
- the location of equipment that needs to be inspected and maintained periodically, such as the heat recovery unit and the fans of the mechanical ventilation system, the inverter in case of installation of photovoltaic modules and the storage unit in case of installation of modules with solar collectors.

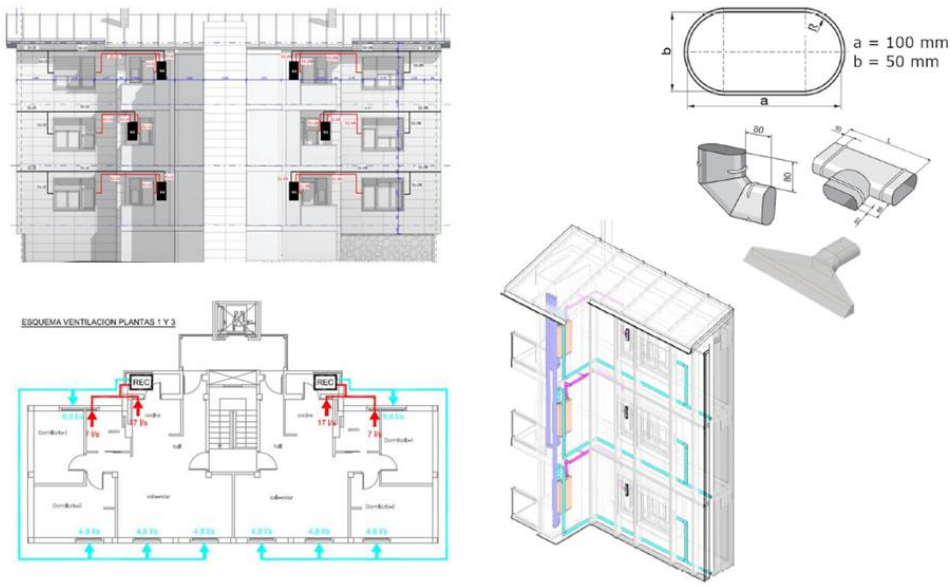

Figure 24 - Durango demonstrator. Mechanical ventilation system

For example, in the case of Durando (Figure 24), the heat recovery units were placed in the balconies on the north side, while the ducts were placed in the gap between the existing building and the new modules.
Particular attention during the detailed design should also be paid to any possible incompatibilities that might arise during installation. Although the system is adaptable to most existing buildings, it remains less flexible than a traditional external insulation solution.
Another useful lesson comes, again, from the Durango demonstrator where incompatibilities were identified in the eaves of the pitched roof. In these locations, the standard installation with a standard crane system was not possible, as the roof overhang prevented the panels from getting close to the brackets anchored to the structure. It was necessary to modify the fastening process of the upper façade panels. A special tool that avoided the roof eaves was developed. This tool allowed to bring the panels closer to the facade, avoiding the roof eaves, and to proceed with their fastening. (Torres, et al., 2021)

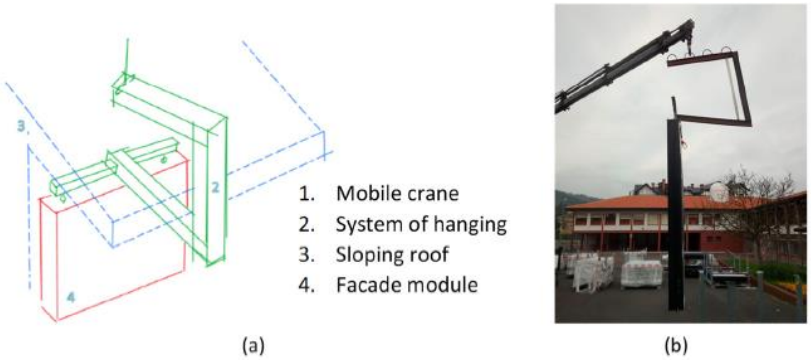

Figure 25 - Durango demonstrator. (a) Fastening system meeting with sloping roof; (b) designed tooling (Torres, et al., 2021)

Although a solution has been found, this case remains emblematic of the need to take care, already at the design stage, of the system installation procedures in order to avoid possible incompatibilities that could raise issues during installation.

7 Conclusions

As expressed earlier, this describes the guidelines for supporting the decision-making stages of the whole renovation process for residential buildings.

The first part is dedicated to the description of the innovative elements introduced by the project, namely the façade system (Chapter 0) and the tools to support the decision-making process during the planning and design phases (Chapter5), namely:

- RenoZEB Dashboard
- Modelling and simulation tools provided by CYPE
- Knowledge Based Engine (KBE)

The second part (Chapter 6), the core of the document, defines the procedure to be followed for designing with the RenoZEB façade system in the context of full renovation projects. Emphasis is placed on the elements introduced by the project, specifying how and when they are to be used throughout the process. Economic analysis is addressed during the Design phase (paragraph 6.2) by describing the approach adopted to estimate the property value increase, which is essential to take into account the multiple benefits resulting from the use of the RenoZEB façade system.