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DELIVERABLE D7.9
Integrated BIMERR Renovation Decision Support System 1

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The BIMERR project consortium is composed of:		
FIT	Fraunhofer Gesellschaft Zur Foerderung Der Angewandten Forschung E.V.	Germany
CERTH	Ethniko Kentro Erevnas Kai Technologikis Anaptyxis	Greece
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AUTHORS LIST

Leading Author (Editor)			
Surname	**First Name**	**Beneficiary**	**Contact email**
Fenz	Stefan	Xylem	fenz@ylem.tech

Co-authors (in alphabetic order)				
#	**Surname**	**First Name**	**Beneficiary**	**Contact email**
1	Bergmayr	Julia	Xylem	bergmayr@xylem.tech
2	Giannakis	Giorgos	Hypertech	g.giannakis@hypertech.gr
3	Hanel	Tobias	FER	thanel@ferrovial.com
4	Heurix	Johannes	Xylem	heurix@xylem.tech
5	Krauss	Veronika	FIT	veronika.krauss@fit.fraunhofer.de
6	Manesis	Fotis	CONKAT	fmanesis@konkat.gr
7	Neubauer	Thomas	Xylem	neubauer@xylem.tech
8	Papapolyzos	Thomas	Hypertech	thomas@hypertech.gr
9	Ratajczak-Jeziorska	Julia	BX	julia.ratajczak@budimex.pl
10	Swiezewski	Piotr	BX	piotr.swiezewski@budimex.pl
11	Tavakolizadeh	Farshid	FIT	farshid.tavakolizadeh@fit.fraunhofer.de
12	Tsakiris	Thanos	CERTH	atsakir@iti.gr
13	Wachter	Christoph	Xylem	wachter@xylem.tech
14	Wellner	Florian	Xylem	wellner@xylem.tech

REVIEWERS LIST

List of Reviewers (in alphabetic order)				
#	**Surname**	**First Name**	**Beneficiary**	**Contact email**
1	Sumereder	Anna	BOC	Anna.Sumereder@boc-eu.com
2	Lampathaki	Fenareti	Suite5	fenareti@suite5.eu

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0.90	Xylem	28.10.2020	Revision after internal review
1.00	Xylem	29.10.2020	Submission to the EC

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

Acronym	Meaning
BEP	Building Energy Performance
BIF	BIMERR Interoperability Framework
BIM	Building Information Modeling
BIMERR	BIM-based holistic tools for Energy-driven Renovation of existing Residences
DSS	Decision Support System
EPW	EnergyPlus Weather Format
IFC	Industry Foundation Classes
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
MU	Monetary Unit
obXML	Occupant Behavior - XML Schema
PV	Photovoltaics
RenoDSS	BIMERR Renovation Decision Support System
UI	User Interface
XML	Extensible Markup Language

EXECUTIVE SUMMARY

This document describes the BIMERR Deliverable D7.9 “Integrated BIMERR Renovation Decision Support System 1” and concludes the first iteration of the development activities in T7.5 “Decision Support System Engine and UI Integration”. The main aim of this task is to develop RenoDSS (Renovation Decision Support System) and put forward an intuitive, BIM-based, and easy-to-use interface that illustrates the renovation options, evaluates their impact on the building performance and guides through various alternatives towards the optimal choice for given boundary constraints (such as size of intervention, budget, target energy savings, etc.). In its first version, BIMERR RenoDSS enables the user to: (i) calculate and visualize the energy, sustainability and economic KPIs of a given building configuration, (ii) set corresponding target KPIs for the renovation, (iii) choose renovation measures from a list of pre-configured renovation measures, (iv) automatically generate renovation scenarios which meet the target KPIs and are based on the chosen renovation measures, and (v) select the most suitable renovation scenario by sorting, filtering, and comparing their KPIs.

The BIMERR RenoDSS is based on state-of-the-art technologies and three layers: (i) the Presentation Layer, which allows the user to load projects, set target renovation KPIs, select potential renovation measures, and identify appropriate renovation scenarios with the RenoDSS decision support component, (ii) the Business Logic Layer which generates renovation scenarios based on the current building configuration and potential renovation measures selected and configured by the user, and (iii) the Data Layer to store global and project-specific renovation measures, potential renovation scenarios and their KPIs.

In the second release of BIMERR RenoDSS we plan to provide: (i) more detailed information on single renovation measures within the scenario view, such as investment cost and quantity (pieces, m^2, m^3, etc.) of each measure, (ii) the possibility to enter and visualize monetary units in renovation project-specific currencies, (iii) PDF reports with detailed information on selected renovation scenarios, (iv) a downloadable IFC file for each renovation scenario, (v) visualization of the current building and renovated building configuration based on the corresponding IFC files (based on third-party libraries), (vi) a context-aware online user manual which describes the RenoDSS functionality within each view, and (vii) internationalization to support multiple languages within the user interface.

1. INTRODUCTION

The goal of the European Green Deal is to make Europe the first climate-neutral continent with no net emissions of greenhouse gases by 2050[1]. Increasing the renovation rate of buildings is a key initiative to drive energy efficiency in the sector and contribute to the European Green Deal objectives[2].

In this context, the main aim of RenoDSS is to put forward an intuitive, BIM-based, and easy-to-use interface that illustrates the building's renovation options, evaluates their impact on the building performance and guides the user through various alternatives towards the optimal choice for given boundary constraints (such as size of intervention, budget, target energy savings, etc.). RenoDSS provides a novel renovation configurator that allows the user to explore alternative renovation interventions.

1.1 BACKGROUND

Nielsen et al. (2016) reviewed related approaches in the field of building renovation decision support systems. From the 43 reviewed approaches, 13 approaches suggest renovation actions and automatically generate design alternatives based on a set of predefined criteria. Two approaches which closely relate to RenoDSS are Jalaei et al. (2015) and Kamari et al. (2019). Jalaei et al. (2015) developed a decision support system (DSS) as a Revit plug-in, which calculates sustainability, finance, and social wellbeing KPIs based on the building's BIM model to efficiently optimize the selection of sustainable building components at the conceptual design stage of building projects. The DSS relies on numerical models to generate and simulate alternative renovation scenarios, rank the alternatives, and enable the user to select the most suitable one. The renovation scenarios are evaluated by the Life Cycle Cost (LCC) method to analyze and compare the operational cost of the whole building. Kamari et al. (2019) developed PARDIS, a BIM-based decision support system, which (i) generates and evaluates dwelling renovation scenarios through specific renovation typologies and constraints, (ii) evaluates energy, finance, and comfort KPIs and, (iii) visualizes the generated renovation scenarios. The PARDIS prototype is implemented as a Revit[3] plug-in and has been empirically evaluated on an apartment block in Denmark.

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[1] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en, last access: 05.10.2020

[2] https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en, last access: 05.10.2020

[3] https://www.autodesk.com/products/revit/overview, last access: 05.10.2020

In contrast to existing approaches, RenoDSS is a web-based system that can be collaboratively used by multiple users independent of closed-source BIM software. It uses the open industry standard IFC for exchanging building information. Besides finance, energy, and comfort KPI calculation, it also provides KPIs for urban planning purposes. The RenoDSS software architecture is modularized and open to external components (e.g., BIMERR Interoperability Framework). The RenoDSS data management module (see Section 2.3) controls the communication between RenoDSS modules (LCA/LCC, building energy performance, and urban planning), the BIMERR Material and Component Database, and the BIMERR Interoperability Framework. Based on the baseline building configuration and the user's renovation preferences, the RenoDSS scenario generator (see Section 2.5) generates potential renovation scenarios and passes them via the data management module to the RenoDSS modules for calculating the KPIs of each generated renovation scenario.

By taking into account the current (as-is) building characteristics, information about its installed equipment as well as information about connections to utility networks and interaction with other buildings, RenoDSS aims to improve on the accuracy of estimations and projections compared to existing renovation planning approaches.

1.2 Scope and Objectives of the Deliverable

D7.9 "Integrated BIMERR Renovation Decision Support System 1" reports the development activities in the context of Task T7.5 "Decision support system engine and UI integration" of WP7 "Renovation Decision Support System". It documents the first version of BIMERR RenoDSS.

The objective of this document is to give an overview and documentation of the first stable release of BIMERR RenoDSS and describe:

- Functionalities of BIMERR RenoDSS
- Technology stack
- Communication within the BIMERR RenoDSS modules
- Assumptions and restrictions of the first release
- Installation instructions
- Usage walkthroughs
- Licensing

BIMERR RenoDSS will be delivered in two releases. The second release of BIMERR RenoDSS will be built on the outcome of this deliverable and will contain all planned functionality and enhancements based on the feedback of the pre-validation and validation activities (WP8).

1.3 RELATION TO OTHER TASKS/DELIVERABLES

T7.5 “Decision support system engine and UI integration” and therefore D7.9 “Integrated BIMERR Renovation Decision Support System 1” are related to the following BIMERR deliverables:

- D3.1 “Stakeholder requirements for the BIMERR system”: the business scenarios, use cases, and requirements described in D3.1 are the basis for the development of BIMERR RenoDSS.
- D3.3 “BIMERR evaluation methodology”: energy, economic and sustainability KPIs described in D3.3 are calculated by the RenoDSS modules (LCA/LCC, energy, and urban planning).
- D3.6 “BIMERR system architecture final version”: the final version of the BIMERR architecture provided an overview on the BIMERR components, how they communicate to each other and how BIMERR RenoDSS is embedded in the BIMERR Framework.
- D4.6 “Building Information Query Builder Creation”: the query examples collected in context of T4.6 supported the design of the endpoint methods with which BIMERR users and components can retrieve data from the BIMERR Material and Component Database.
- D4.8 “Integrated Interoperability Framework 1”: supported the preparation of RenoDSS for the future integration into the BIMERR interoperability framework.
- D7.1 “Populated Material/Component Databases 1”: the developed building material and component database is used to provide RenoDSS with material and component data for the energy, economic, and sustainability KPI calculation.
- D7.3 “Life Cycle Cost/Assessment Module 1”: the LCA module calculates the economic and sustainability KPIs of the renovation scenarios.
- D7.5 “Building Energy Modeling Module 1”: the building energy performance module calculates the energy KPIs of the renovation scenarios.
- D7.7 “Urban Planning Module 1”: the urban planning module calculates the urban planning KPIs of the renovation scenarios.
- T8.1 “External information availability and sourcing”: ensures that data relevant for pre-validation and validation sites are available.

1.4 STRUCTURE OF THE DOCUMENT

Section 1 describes the scope/objectives of the deliverable and its relations to other tasks and deliverables. Section 2 gives an overview of BIMERR RenoDSS, its architecture, functionalities, BIF integration plans, technology stack, assumptions, restrictions, installation instructions and licensing. Section 3 provides and end-to-end walkthrough to show the functionalities on a sample building. Section 4 outlines the research and development plans for the second iteration of BIMERR RenoDSS due in M30.

2. BIMERR RENODSS

2.1 OVERVIEW

The main aim of RenoDSS is to put forward an intuitive, BIM-based, and easy-to-use interface that illustrates the building's renovation options, evaluates their impact on the building performance and guides the user through various alternatives towards the optimal choice for given boundary constraints (such as size of intervention, budget, target energy savings, etc.). RenoDSS offers a renovation configurator that allows the user to explore alternative renovation interventions.

The first version of BIMERR RenoDSS is available at[4]: https://renodss.xylem-technologies.com/

2.2 ARCHITECTURE

Based on the BIMERR architecture (see Deliverable D3.6), Figure 1 shows the architecture of RenoDSS and its modules.

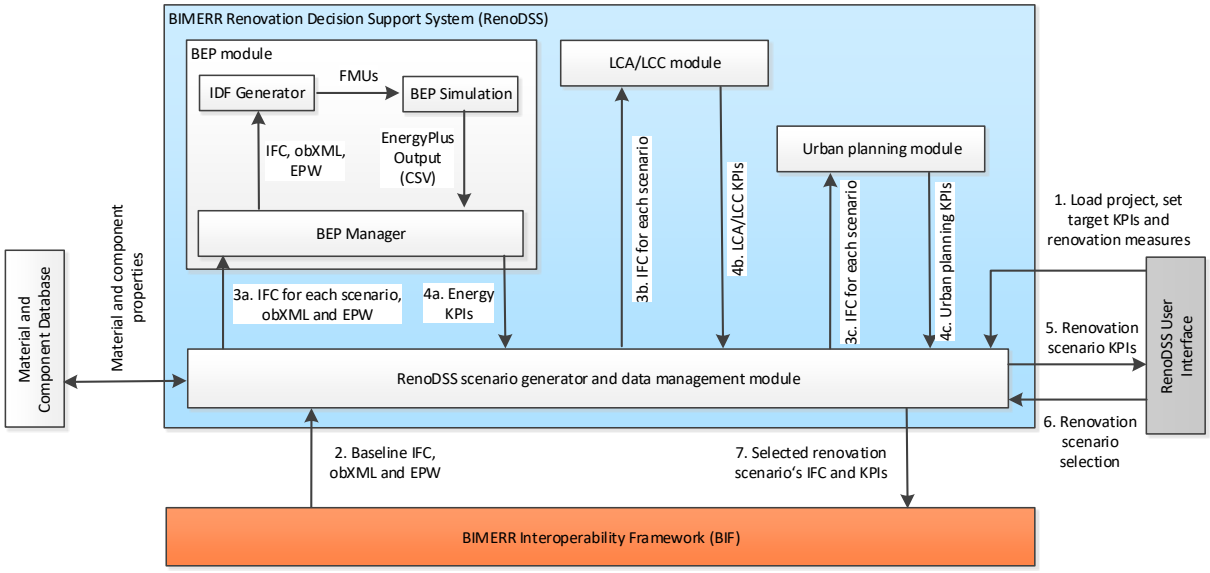

Figure 1: Architecture of the BIMERR renovation support tools

RenoDSS communicates via the RenoDSS Data Management Module with the LCA/LCC module, the BEP (Building Energy Performance) module, the Urban Planning module, the RenoDSS UI, the BIMERR

[4] For security reasons the access to RenoDSS is restricted to authorized IP addresses. Please send an email to support@xylem-technologies.com to request access to RenoDSS.

Material and Component Database, and the BIMERR Interoperability Framework. A detailed description of the data flow between the modules can be found in Section 2.3.

2.3 DATA MANAGEMENT MODULE

The data management module coordinates the RenoDSS data flow (see Figure 1) as follows:

1. The data flow starts with the user selecting a specific renovation project via the RenoDSS UI. The selected renovation project is sent by the RenoDSS UI to the data management module.
2. The data management module queries the baseline IFC (building information model of the current building state), obXML (occupant behaviour model) and EPW (weather data) files for the selected renovation project from the BIMERR Interoperability Framework (BIF). Currently this step uses mocked data as RenoDSS is intended to be integrated with the BIMERR Interoperability Framework (BIF) by its second release that is expected on M30. Based on the renovation measures selected by the user in the RenoDSS UI, RenoDSS will generate one modified IFC file per renovation scenario. This IFC file contains the building information model of the renovated building. Please see Section 2.5 for detailed information on how the renovation scenarios are generated.
3. For each renovation scenario, the data management module sends the corresponding IFC file to the BEP (building energy performance), LCA/LCC (life cycle assessment), and urban planning modules. To the BEP module, it also sends the obXML and EPW files previously retrieved from the BIF.
4. The energy, LCA/LCC, and urban planning KPIs for each renovation scenario are calculated by the respective modules and are returned to the data management module.
5. The retrieved KPIs are forwarded to the RenoDSS UI and are presented to the user via the RenoDSS decision support UI.
6. The user identifies and selects the most promising renovation scenario by using the KPI filter and sorting mechanism of the RenoDSS decision support UI.
7. The IFC file and the KPIs of the selected renovation scenario are provided by the data management module to the BIF for further usage in other BIMERR components.

The data management module communicates with the BIMERR Material and Component Database in two cases:

1. Modification of the material and component database content by the user via the RenoDSS UI.

2. Retrieving material and component data for extending the IFC files with the necessary material and component properties before sending the IFC files to the BEP, LCA/LCC, and urban planning modules.

In the following section, the definition and selection of renovation measures as mentioned in Step 2 of the data flow is described.

2.4 RENOVATION MEASURES

The RenoDSS user selects pre-defined renovation measures to enable the generation of renovation scenarios. The renovation measures are defined by the RenoDSS admin user and can be modified by the RenoDSS user within the renovation project context.

2.4.1 Definition of global renovation measures

The RenoDSS admin user defines global, i.e. available to all projects, renovation measures within the categories façade, roof, floor, fenestration, lighting, heating system, hot water, solar, and cooling system (see Figure 2).

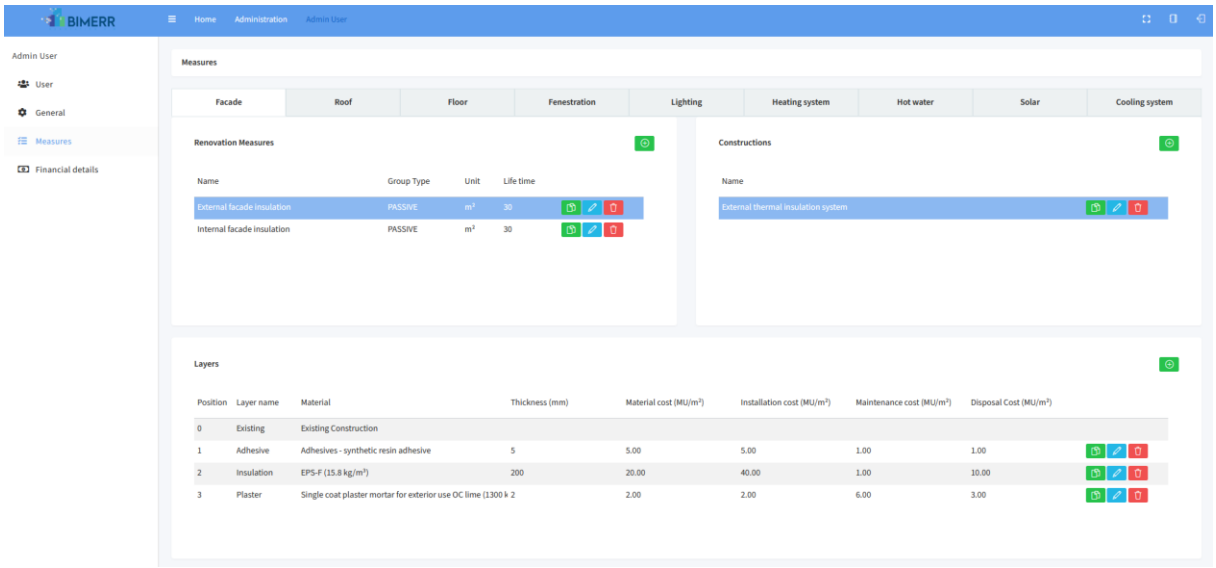

Figure 2: Definition of global renovation measures (constructions)

In each renovation measure category (as shown in Figure 3), renovation measures can be defined and described by a name, type (active, passive, or renewable), reference unit (m^2, m^3, mm or pcs), lifetime in years, IFC element types (e.g., IfcWall or IfcRoof) on which the renovation measure is applied, and the side of the IFC element the renovation measure is applied (conditioned or unconditioned side).

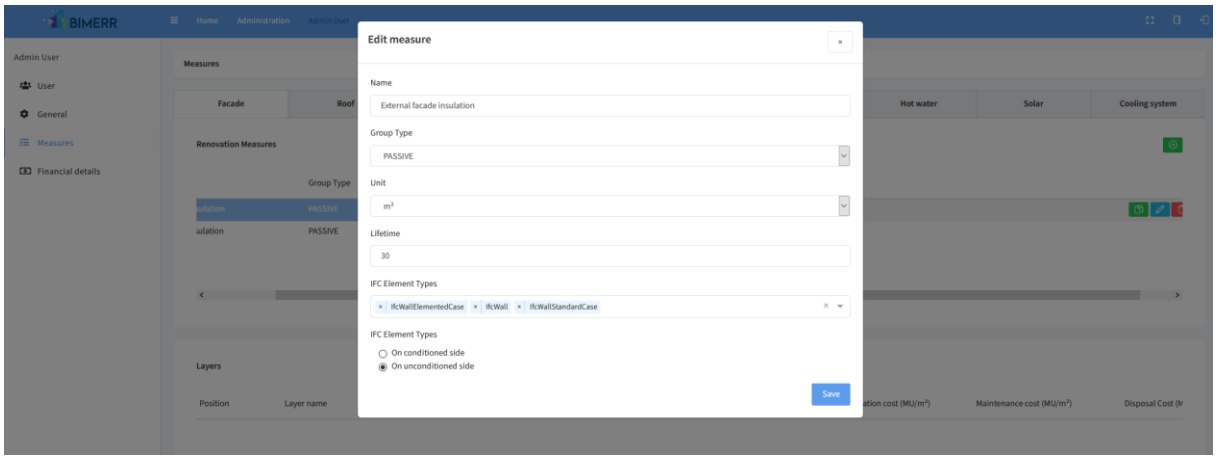

Figure 3: Edit measure

Within the renovation measure categories façade, roof and floor, constructions can be added to renovation measures (see top right in Figure 2). Each construction is described by layers (see bottom in Figure 2). Each construction contains on Position 0 the existing construction on which the renovation measure is applied. Starting from Position 1 the RenoDSS admin user defines the layers as shown in Figure 4. Each layer is described by a name, a material from the BIMERR material and component database, thickness of the applied material, and material, installation, maintenance, and disposal cost in monetary units (MU) per reference unit of the renovation measure (e.g., m²).

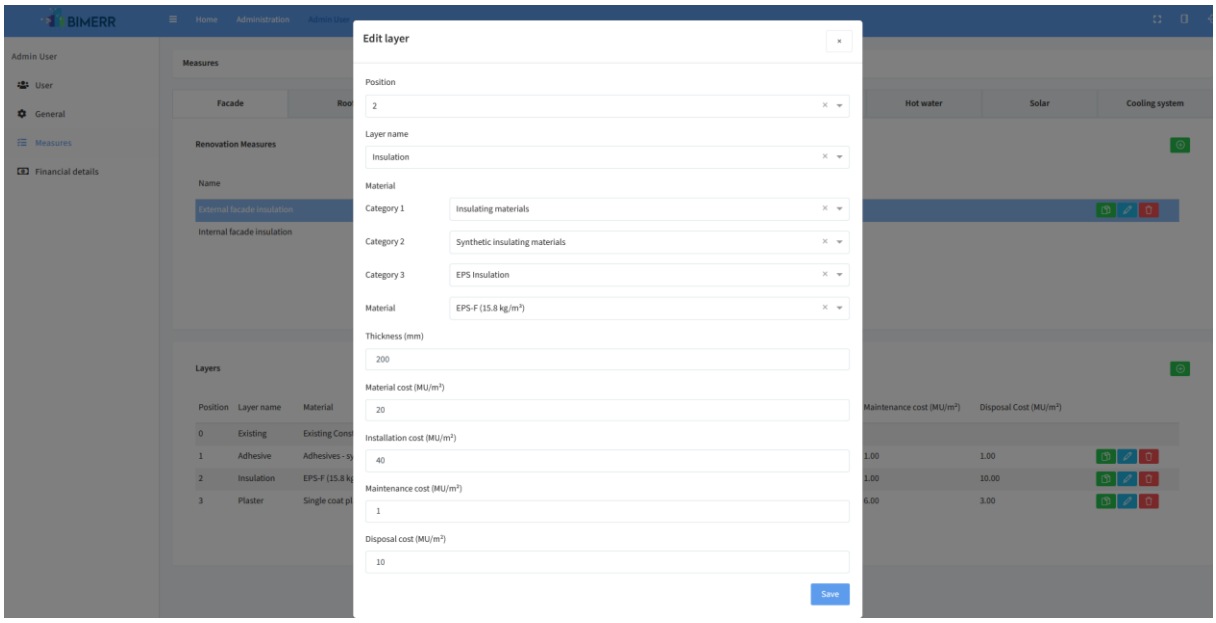

Figure 4: Layer editing

To allow for alternative materials and thicknesses per layer, layer information can be copied and assigned to the same position within the construction. As an example, Figure 5 shows two alternative

thicknesses of the insultation material in Position 2. This enables the renovation scenario generator to generate a renovation scenario for each insulation thickness and support the user at comparing both renovation scenarios. See Section 2.5 for further details on how the renovation scenarios are generated.

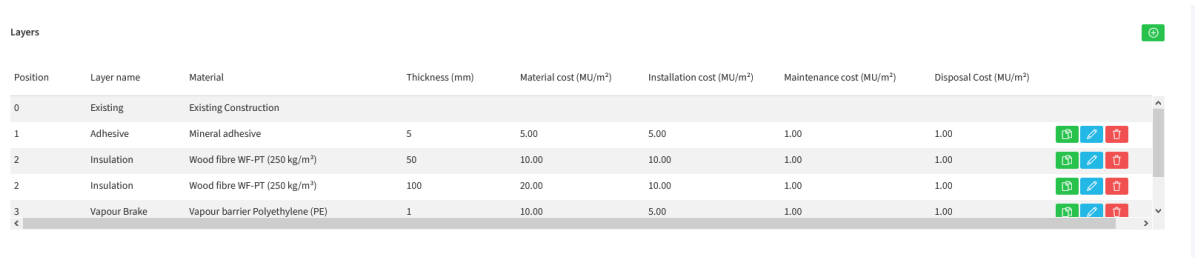

Figure 5: Alternative materials and thicknesses per layer

Within the renovation categories fenestration, lighting, heating system, hot water, solar, and cooling system, renovation measures are defined by components, i.e., technical systems which are treated as a unit and not as a composition of materials. Figure 6 shows the definition of renovation measures on the component level. For each renovation measure, the RenoDSS admin user defines more than one component from the BIMERR material and component database as potential renovation measure implementation.

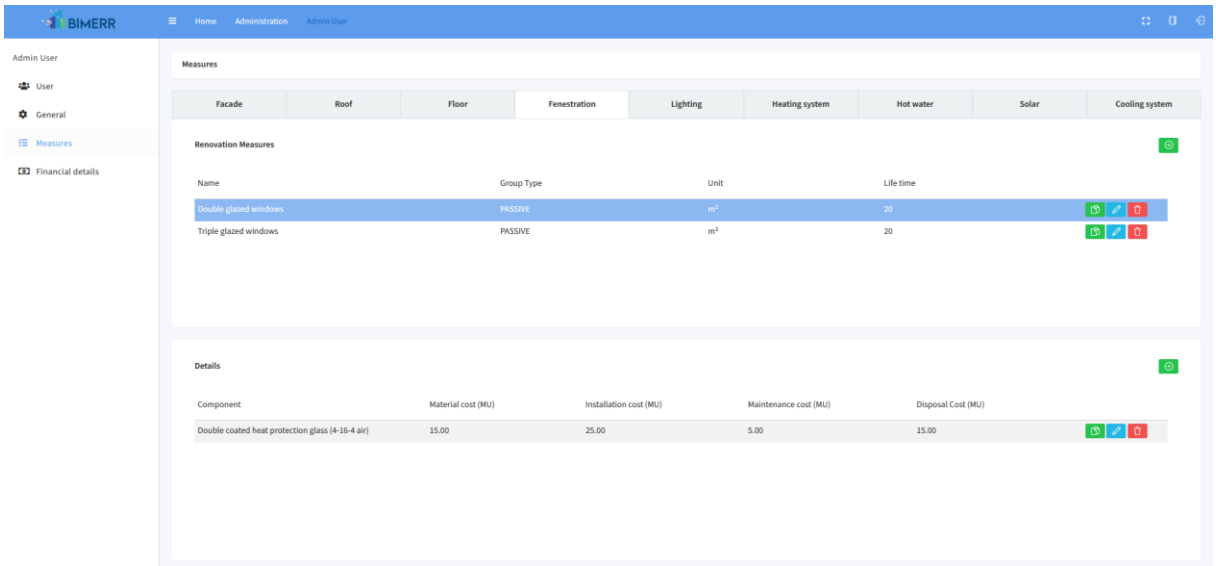

Figure 6: Definition of global renovation measures (components)

2.4.2 Selection and modification of project-specific renovation measures

Based on the global renovation measures defined by the RenoDSS admin user, the RenoDSS user selects those renovation measures which should be applied to a specific renovation project as follows:

1. For each renovation measure category (e.g., façade or roof), RenoDSS identifies those IFC building elements which are relevant to the renovation measure category (based on the IFC elements types such as IfcWall or IfcRoof defined in the renovation measure).
2. RenoDSS groups all IFC building elements with identical constructions and lists them in the dropdown "Building element" – see top left in Figure 7. Grouping identical constructions enables the user to apply renovation measures more efficiently than selecting them for each single IFC element. The user can deselect single IFC elements within the group to prevent the application of renovation measures on these specific IFC elements.
3. The current construction of the selected building element is shown in the top middle area of the user interface. The user must select the conditioned side of the construction to ensure that the scenario generator applies the selected renovation measures on the correct side of the construction.
4. The renovation measures for each building element are selected by the RenoDSS user in the top right area of the user interface. Zero or more renovation measures can be selected.
5. As the application of renovation measures often requires the removal of old construction layers or components, the RenoDSS user must indicate at the construction layers (top middle area of the user interface) which layers are removed at which renovation measure application. Each renovation measure is encoded by its identifier (e.g., A and B) at each layer. By clicking on the buttons, the user can change the colour from green to red and from red to green. Red means this layer is removed when applying the renovation measure. Green means this layer will be kept when applying the renovation measure. E.g., when applying external insulation, the old insulation layer is usually removed before applying the new insulation layer.
6. By selecting a specific renovation measure, its layers are shown in the bottom area of the user interface. The layers are initially copied from the global renovation measures as defined by the RenoDSS admin user and described in Section 2.4.1. After the layers have been copied into the specific renovation project, the RenoDSS user can modify them as needed. E.g., adding/changing layers and materials, modifying costs, etc.

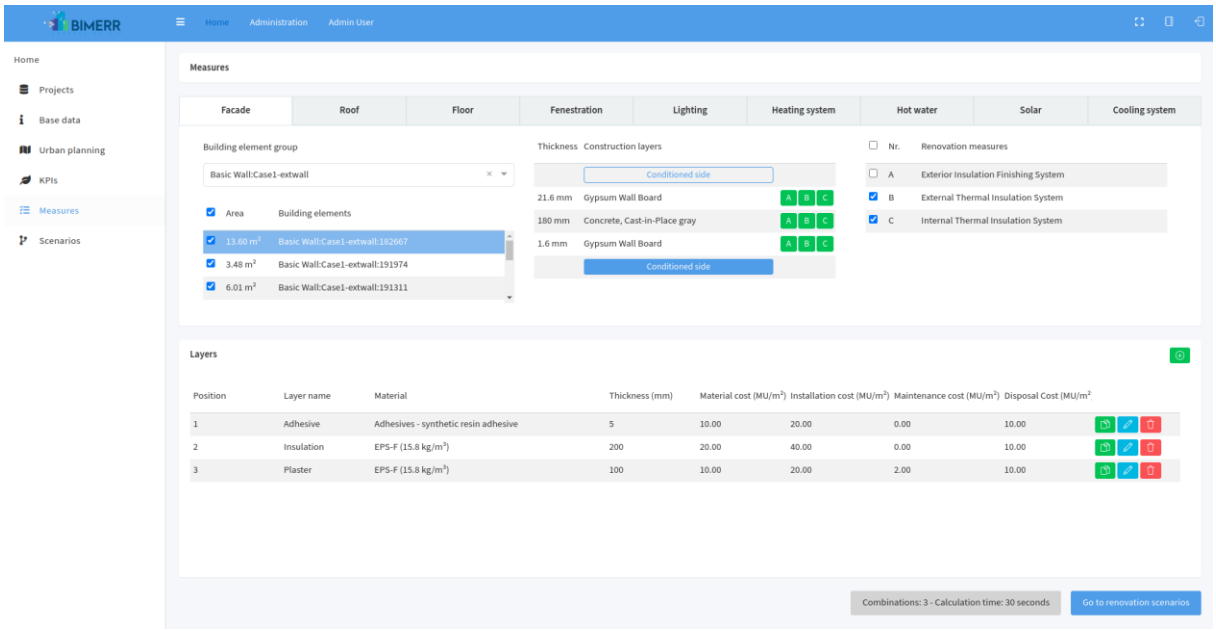

Figure 7: Selection and modification of project-specific renovation measures (constructions)

Figure 8 shows the selection and modification of project-specific renovation measures on the component level. At the component level, building elements are also grouped and we assume that old components are removed before new components are applied as renovation measures.

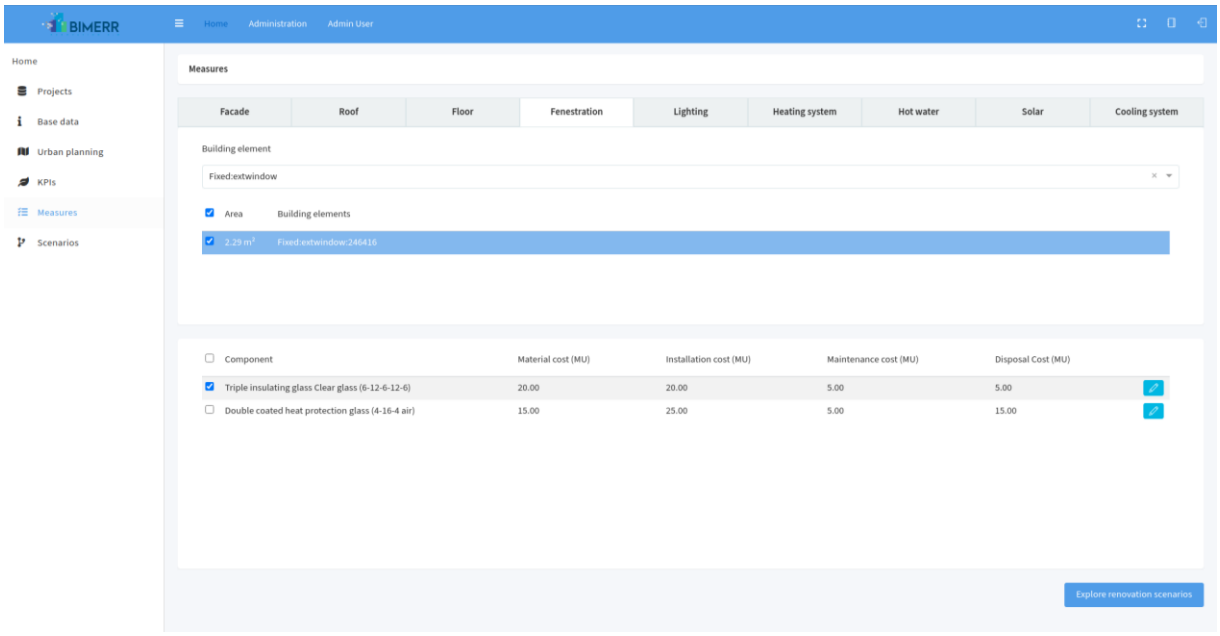

Figure 8: Selection and modification of project-specific renovation measures (components)

In the following section the generation of renovation scenarios as mentioned in Step 2 of the data flow is described.

2.5 SCENARIO GENERATOR

The scenario generator generates IFC files that represent renovated building configurations based on: (i) the IFC representation of the current building configuration, (ii) potential renovation measures selected by the user and their mapping to IFC elements as defined in Table 1, and (iii) a rule set on how these renovation measures can be combined and applied on the building.

2.5.1 Combining renovation measures

Renovation measures such as external wall insulations or new heating systems are technical measures to improve the energy performance, comfort, or life cycle cost of the building. Table 1 shows the renovation measures which are supported by the current implementation of the scenario generator. To reduce the number of potential combinations, it is assumed that only one renovation measure per renovated building element is applied in one renovation scenario. E.g., the façade of a specific building element is either renovated by an external façade insulation or an internal façade insulation but not both at the same time within one renovation scenario.

Table 1: Renovation measure table

Name	Category	IFC element[5]
External thermal insulation system	Façade	IfcWall; IfcWallElementedCase; IfcWallStandardCase
Internal thermal insulation system	Façade	IfcWall; IfcWallElementedCase; IfcWallStandardCase
Flat roof external insulation	Roof	IfcRoof; IfcSlab
Pitched roof internal insulation	Roof	IfcRoof; IfcSlab
Top slab external insulation	Roof	IfcRoof; IfcSlab
Basement ceiling insulation	Floor	IfcSlab
Slab internal insulation	Floor	IfcSlab
Double glazed windows	Fenestration	IfcWindow; IfcWindowStandardCase
Triple glazed windows	Fenestration	IfcWindow; IfcWindowStandardCase
Photovoltaic panel	Solar collector	IfcSolarDevice
Solar thermal collector	Solar collector	IfcSolarDevice
Condensing natural gas boiler	Heating system	IfcBoiler
Air to water heat pump	Heating system	IfcPump
Air to air split units	Cooling system	IfcPump

As described in D7.3, each renovation measure within the category façade, roof and floor is specified by the layers of its construction and the building materials which can be used within the layers. As an example, Figure 9 shows the layer configuration of renovation measure “Top slab external insulation”.

[5] https://standards.buildingsmart.org/IFC/RELEASE/IFC4/ADD2_TC1/HTML/, last access: 10.08.2020

The first layer is the insulation, which is put on top of the existing slab. In this example the insulation can be 200mm cellulose or EPS insulation material with a thickness of 200, 300 or 400mm. The second layer plywood is placed on top of the insulation.

Position	Layer name	Material	Thickness (mm)
1	Insulation	Cellulose spray on insulation (95 kg/m³)	200
1	Insulation	EPS-F (15.8 kg/m³)	200
1	Insulation	EPS-F (15.8 kg/m³)	300
1	Insulation	EPS-F (15.8 kg/m³)	400
2	Board	Plywood and laminated veneer lumber for interior use (375 kg/m³)	35

Figure 9: Renovation measure "Top slab external insulation" and potential building materials for each layer of the construction

As each renovation measure can be implemented by different material/thickness combinations the number of potential renovation scenarios is calculated as follows:

$$RM = \prod_{i=0}^{n} \prod_{g=0}^{l} ((\sum_{j=0}^{m} \prod_{k=0}^{c} NL_c) + 1)$$

- RM: number of renovation scenarios
- i: current renovation measure category façade, roof, floor, fenestration, solar collector, heating system, cooling system
- g: current building element group
- j: current renovation measure in renovation measure category i
- k: current construction or component in renovation measure m
- NL: sum of equal position numbers per layer in construction c or number of equivalent implementations for component c

Description of the RM formula:

Each renovation measure category (façade, roof, etc.) contains specific renovation measures (external thermal insulation system, internal thermal insulation system, etc.). Each renovation measure is implemented by a layer-based construction or a single component and can be applied onto different building element groups (e.g., different types of exterior walls or roofs). Building element groups group building elements with the same characteristics. For example, walls, roofs, slabs and floors with the same construction would be grouped into the same building element group. Table 2 shows the input data for the following example used to describe the RM formula rationale.

Table 2: Calculation of total renovation scenarios - example input data

1: Renovation measure	2: Renovation measure category	3: Building element group	4: Number of valid layer combinations or components	5: Number of combinations per renovation measure category	6: Number of renovation scenarios
External thermal insulation system	Façade	Exterior wall 1	2	(2+2+1)*(2+2+1)=25	25*17*5*3*3*3*2=114.750
		Exterior wall 2	2		
Internal thermal insulation system	Façade	Exterior wall 1	2		
		Exterior wall 2	2		
Flat roof external insulation	Roof	Roof 1	4	(4+8+4)+1=16+1=17	
Pitched roof internal insulation	Roof	Roof 1	8		
Top slab external insulation	Roof	Roof 1	4		
Basement ceiling insulation	Floor	Floor 1	2	2+2=4+1=5	
Slab internal insulation	Floor	Floor 1	2		
Double glazed windows	Fenestration	Windows 1	1	1+1=2+1=3	
Triple glazed windows	Fenestration	Windows 1	1		
Photovoltaic panel	Solar collector	Roof 1	1	1+1=2+1=3	
Solar thermal collector	Solar collector	Roof 1	1		
Condensing natural gas boiler	Heating system	Building 1	1	1+1=2+1=3	
Air to water heat pump	Heating system	Building 1	1		
Air to air split units	Cooling system	Building 1	1	1+1=2	

If a layer-based construction is defined by more than one material/thickness combination per layer position, the total number of possible combinations is the product of the sums of equal position numbers per layer. For example, the construction in Figure 9 would result in 4*1=4 valid layer combinations (4 insulation material/thickness combinations in layer 1 and one in layer 2). Table 2 shows the number of valid layer combinations or components within the fourth column.

As one renovation measure category can be implemented by more than one renovation measure (e.g., double- or triple-glazed windows for renovating the fenestration as shown in Table 2), but the final renovation scenario contains only one renovation measure per renovation measure category[6] and building element group, we must sum up the number of potential renovation measure implementations per renovation measure category and building element group. As it is also possible not to implement any renovation measure, 1 is added to the sum. See Column 5 in Table 2.

As renovation measures can be applied onto different building element groups within one renovation measure category (e.g., renovating different exterior walls with different renovation measures), the number of combinations per renovation measure category is the product of potential renovation measure implementations per building element group plus one for the non-renovation option (see previous paragraph). See Column 5, renovation measure category Façade for an example in Table 2.

Because we assume that only one or none renovation measure is implemented per renovation measure category and building element group in one renovation scenario, we must multiply the number of potential renovation measure category implementations to get the total number of potential renovation scenarios. See Column 6 in Table 2.

2.5.2 IFC file modification

For each renovation scenario, the scenario generator produces an IFC file which represents the renovated building. The IFC file is sent by the data management module to the RenoDSS BEP, LCA/LCC, and urban planning modules for calculating the KPIs of the building.

We use the xBIM Toolkit for loading and modifying the IFC file of the current building configuration as follows:

1. Load baseline IFC file by xBIM Toolkit
2. For each renovation scenario

[6] Under this assumption a renovation scenario would not mix e.g., tripe- and double-glazed windows within one renovation scenario.

a. Identify those IFC elements which must be modified based on the renovation measures selected by the user (e.g., specific IfcWall, IfcRoof or IfcSlab elements)
b. Remove layers (e.g., old insulation layers) as specified by the user
c. Add renovation layers as specified in the renovation scenario
d. Send IFC file for KPI calculation to BEP, LCA/LCC, and urban planning module
e. Retrieve KPIs from calculation modules and store them in decision support data structure

3. Present KPIs of all calculated renovation scenarios in the RenoDSS decision support system to the user

2.6 Technology Stack and Implementation Tools

BIMERR RenoDSS is based on state-of-the-art technologies and three layers:

- The Presentation Layer, which allows the user to load projects, set target renovation KPIs, select potential renovation measures, and identify appropriate renovation scenarios with the RenoDSS decision support component. The user interface is built upon Angular, Typescript, and NGRX Entity/Store.
- The Business Logic Layer is written in Java and generates renovation scenarios based on the current building configuration and potential renovation measures selected and configured by the user. xBIM is used for reading and modifying the IFC files.
- The Data Layer that utilizes PostgreSQL to store global and project-specific renovation measures, potential renovation scenarios and their KPIs.

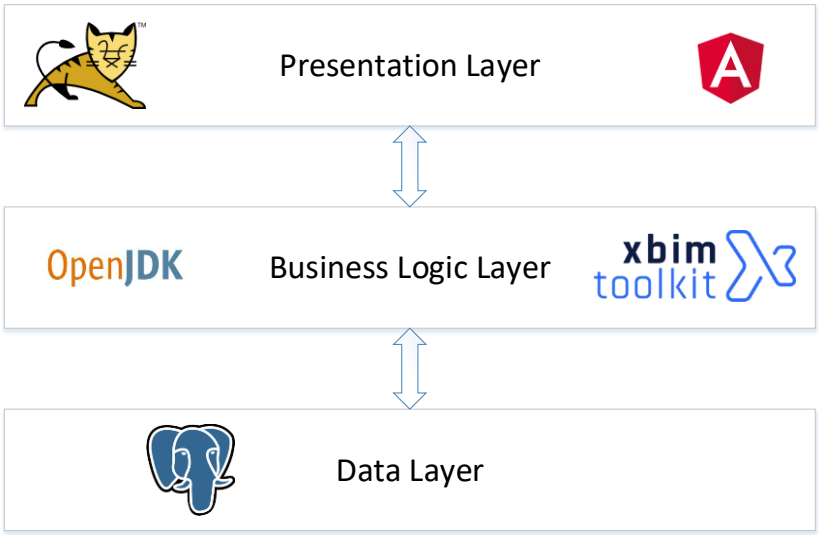

Figure 10: Architecture of BIMERR RenoDSS

BIMERR RenoDSS utilizes the open source technologies and libraries as defined in the following table.

Table 3: Technologies and libraries used in BIMERR RenoDSS

Name of the technology/library	Version	License
Apache Tomcat	9	Apache License 2.0 license
Angular	8	MIT License
Typescript	3.5.3	Apache License 2.0 license
NGRX Entity/Store	8.5.2	MIT-style License
Java OpenJDK	11	GPLv2
Spring Boot	2.2.1	Apache License 2.0 license
Hibernate	5.4.8	LGPL 2.1
PostgreSQL	9.5	PostgreSQL License (similar to BSD/MIT)
xBIM Tookit	5.1	Common Development and Distribution License (CDDL)

2.7 API DOCUMENTATION

RenoDSS utilizes the BEP, LCA/LCC, and urban planning modules to calculate the renovation scenario KPIs. For calculating many renovation scenario KPIs without blocking the RenoDSS user interface, RenoDSS provides an asynchronous interface to communicate with the BEP module which is described in the following. The RenoDSS BEP endpoint is available at

https://renodss.xylem-technologies.com/api/m2m/bep/kpis

To access the REST endpoints via an application such as Postman[7], an API key must be provided in the header of the HTTP request as follows:

- Key: apiKey
- Value: 0bf7366f-919c-4781-bb91-59be80608fe6

[7] https://www.postman.com/, last access: 12.10.2020

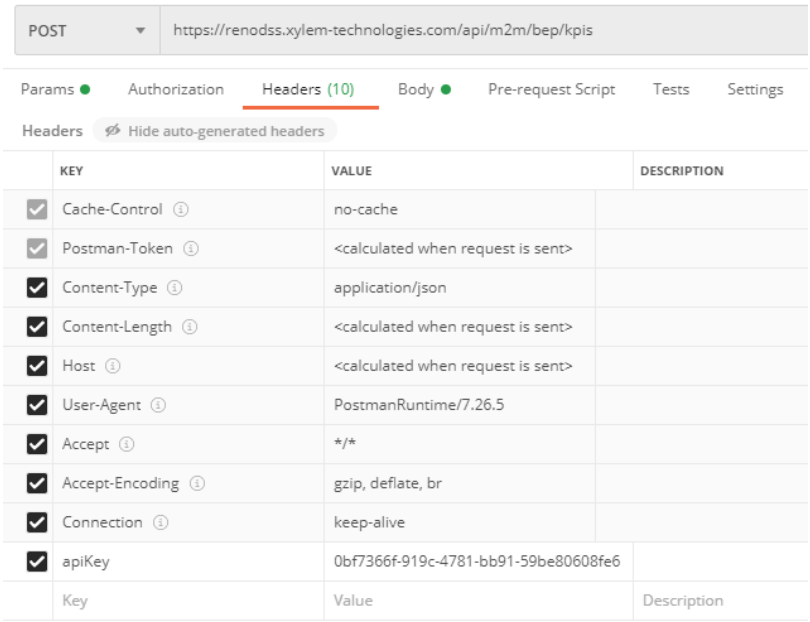

Figure 11: Postman request with API key

The POST request must submit the calculated KPIs as shown in Section 6 (Annex). It is important that a valid renovation scenario ID, project ID, and user ID is provided with the request. If project and scenario ID do not match, the HTTP status code 400 "Bad Request" is returned. If the API key is not provided correctly, the endpoint returns 401 or 403 HTTP status codes.

2.8 Assumptions and Restrictions

As the development of BIMERR applications is still ongoing and validation activities have not started yet, the first release of BIMERR RenoDSS is based on the following assumptions/restrictions:

- Currently the scenario view shows only basic information regarding the involved renovation measures. In the next development iteration, it is planned to show more detailed information on renovation measures within the scenario view (e.g. investment cost or quantity of each measure).
- To reduce the large number of potential renovation measure combinations, only one renovation measure per renovated building element is applied in one renovation scenario.
- Costs are currently entered and shown in abstract monetary units. It is planned to implement currency conversion schemas in the next development iteration.
- No written reports (e.g., PDF reports) for created renovation scenarios are provided. This makes it hard to distribute the RenoDSS results to relevant stakeholders. In the next version PDF reports will be implemented.

- Currently no IFC file is provided for the created renovation scenarios. As such further editing or refining renovation scenarios by other software tools (e.g., Revit or ArchiCAD) is not possible. The plan is to provide IFC file download per renovation scenario in the next RenoDSS release.
- No visualization of the current building and renovation building configuration is implemented. To support the visual user experience, it is planned to implement an IFC-based building visualization (based on third-party libraries) in the next development iteration.
- No guidance for the user. In the next RenoDSS release we will implement a context-aware online user manual which describes the RenoDSS functionality within each view in simple terms to the user.
- Currently RenoDSS is available in English only. We plan to support multiple languages within the user interface.

2.9 Installation Instructions

BIMERR RenoDSS is accessible via a web-based GUI, and therefore it does not require installation or downloading of any component to use it.

2.10 Licensing

As parts of RenoDSS are based on and integrated into the Xylem business intelligence platform it is a closed source component. The Xylem platform provides, except from the core business logic which was developed in BIMERR, all components to provide the RenoDSS functionality to the user (e.g., UI elements, user management, security mechanisms, software architecture, etc.).

3. BIMERR RENODSS END-TO-END USAGE WALKTHROUGH

After logging into BIMERR RenoDSS, the project view (see Figure 12) is presented to the user. The user's renovation projects are visualized on a map and a list view.

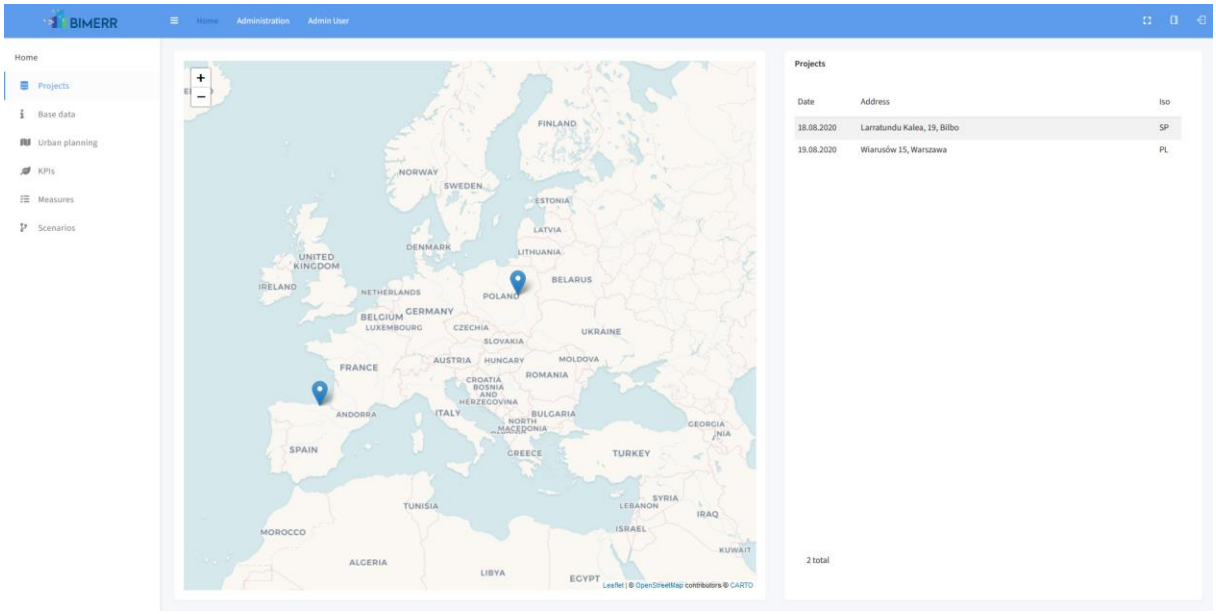

Figure 12: RenoDSS - project view

By clicking on a project in the list view, the project data is shown (see Figure 13). A map view visualizes the building's location and neighboring buildings. The project information shown in the top right area is extracted from the building's IFC file (building height, external wall area, usable floor area) and user-defined meta data (address and region).

Input parameters for the LCA/LCC module (see Deliverable D7.3 for further details) are configured in the bottom area of the project view UI. Data for: (i) analysis period and rates, (ii) energy prices and emissions, and (iii) environmental cost is initially loaded with region-specific default values and can be adjusted by the user. If no default values for the specific region exist, global default values are loaded.

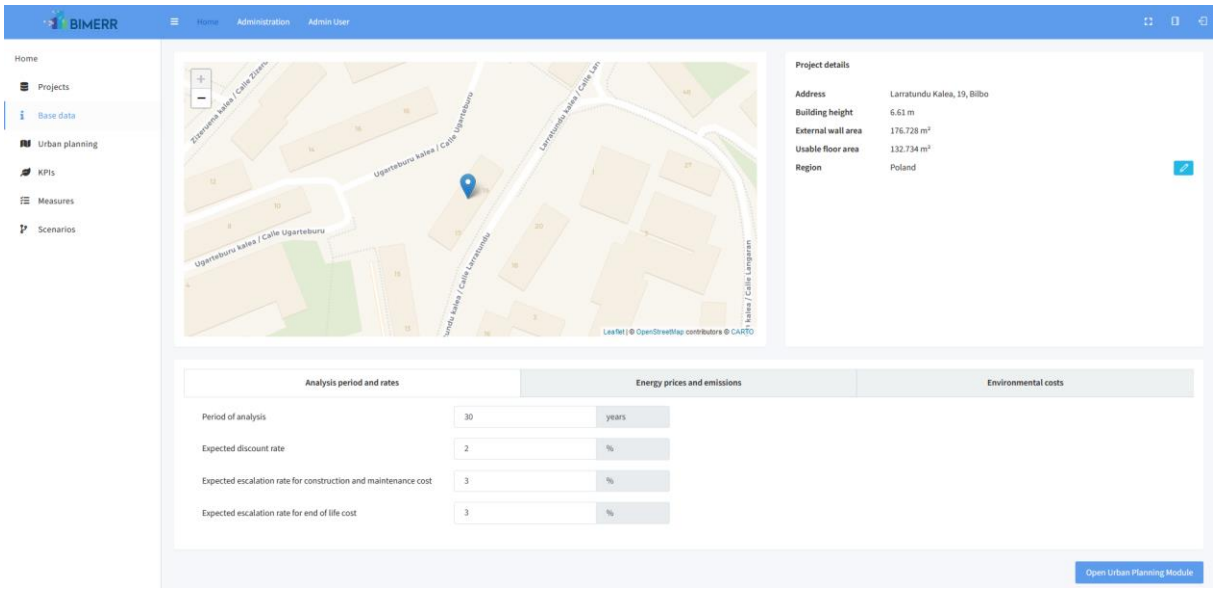

Figure 13: RenoDSS – project data view

Within the RenoDSS urban planning view (see Figure 14 and Deliverable D7.9 for further details), the user can add the energy production and consumption profiles of the building and its neighboring buildings to calculate energy flows between the buildings. RenoDSS uses the energy flow data to estimate if renewable renovation measures such as PV can contribute to district-wide energy efficiency goals.

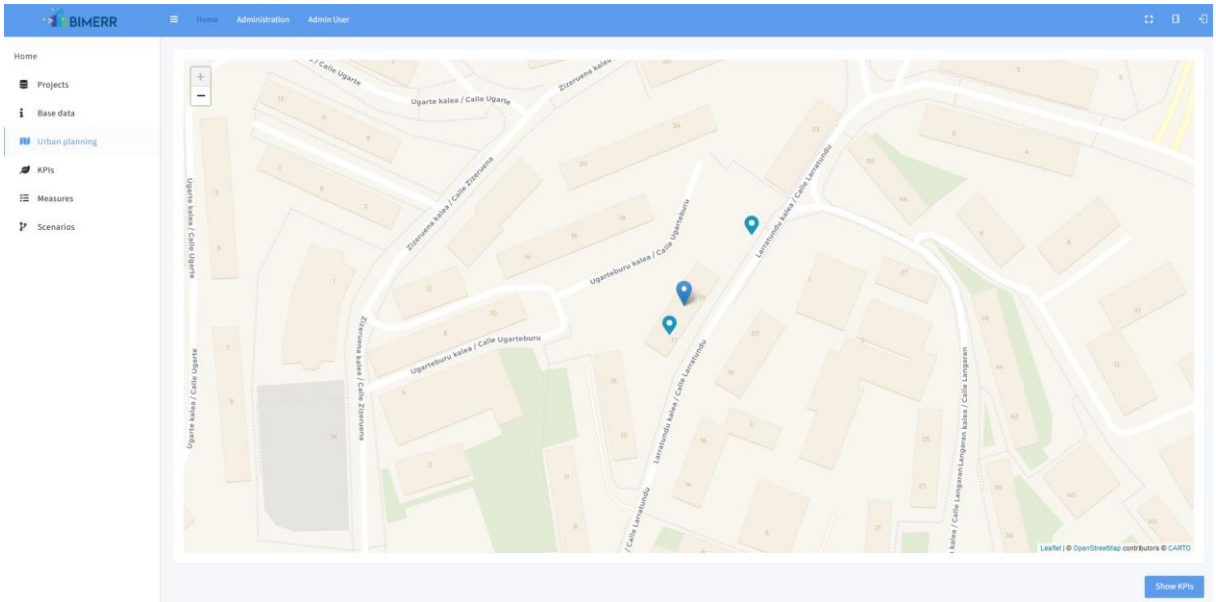

Figure 14: RenoDSS - urban planning view

Within the RenoDSS KPI view (see Figure 15) the KPIs calculated by the LCA/LCC module (see Deliverable D7.3), the Building Energy Performance module (see Deliverable D7.5), and the urban planning module (see Deliverable D7.7) are presented within the categories Economic, Sustainability, Energy, and Comfort to the user. The calculated KPI is shown in column “Status quo”, the target value can be set in column “Target”. Please note that the first RenoDSS version does not support Comfort KPI calculation and setting the corresponding target KPIs. With the renovation scenario view (see Figure 17) RenoDSS will only show renovation scenarios with KPIs that meet the target KPIs set by the user.

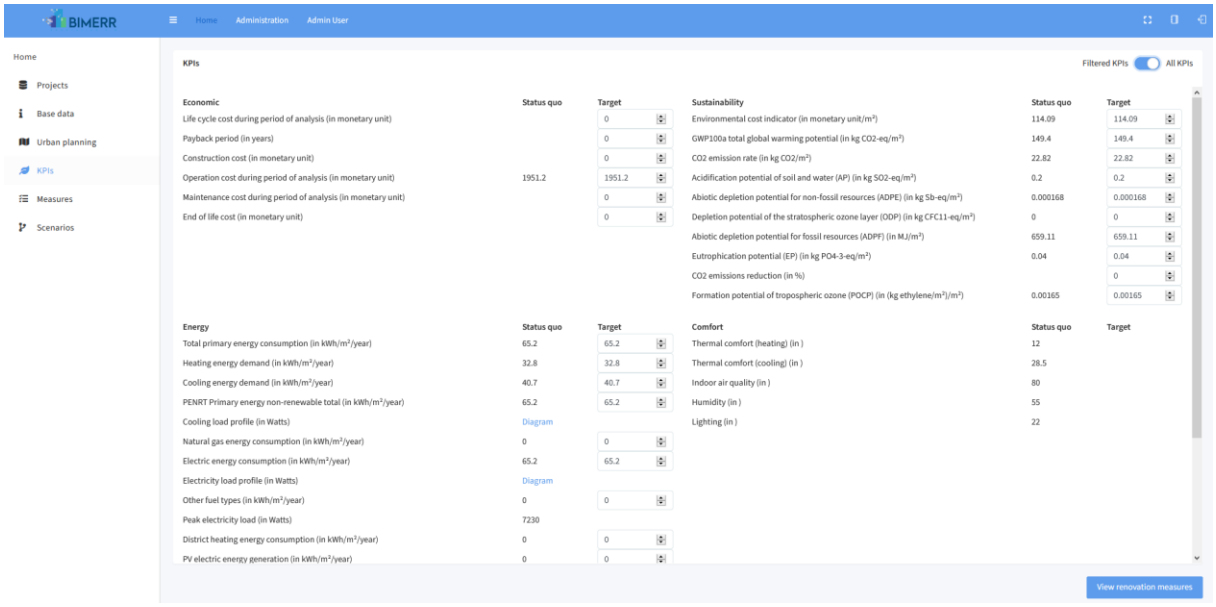

Figure 15: RenoDSS - KPI view

With the renovation measure view (see Figure 16), the user chooses renovation measures which are relevant for the building. Please see Section 2.4 for further details on this process.

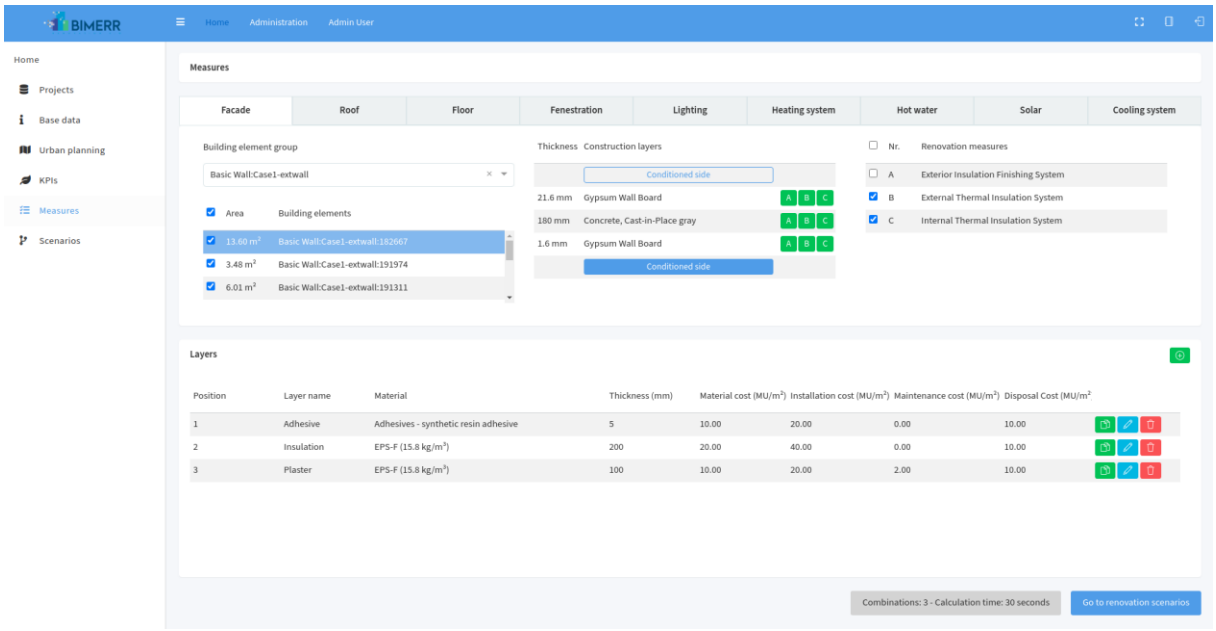

Figure 16: RenoDSS - renovation measure view

Within the renovation scenario view (see Figure 17), the results of the RenoDSS scenario generator (see Section 2.5 for further details) and the KPI calculations for each generated scenario are shown. The renovation scenarios are shown in the UI's top right area. Each renovation scenario is described by its most important KPIs, the list view allows for sorting all scenarios by KPIs. In the UI's left area sliders can be used to filter the renovation scenarios by their KPIs. By clicking on a renovation scenario, the renovation measures of this specific scenario are shown in the UI's bottom right area.

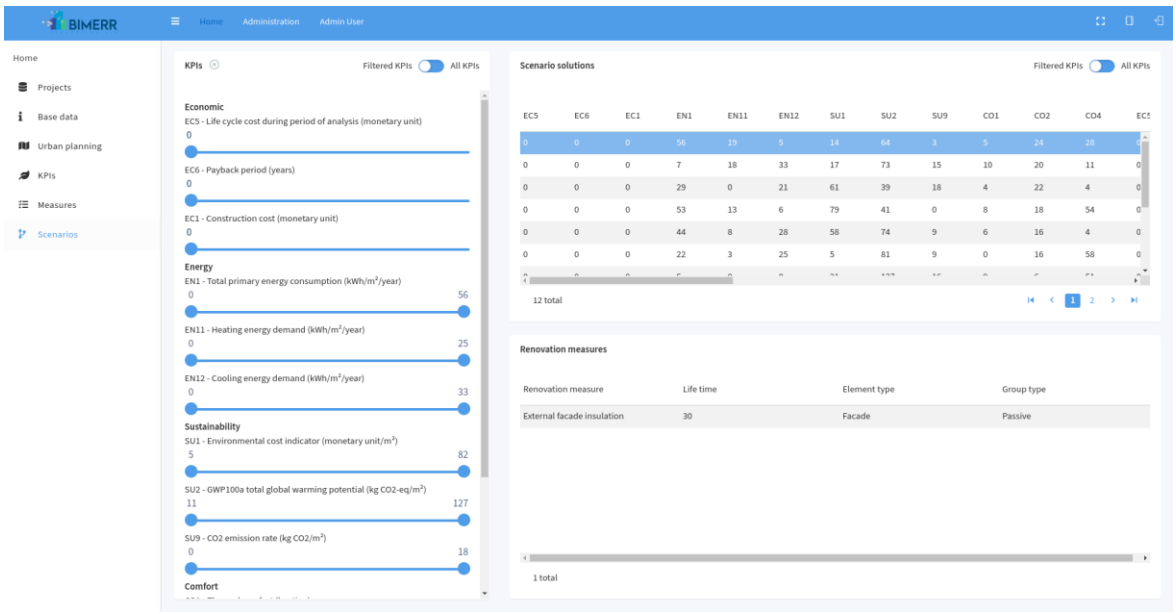

Figure 17: RenoDSS - renovation scenario view

4. CONCLUSIONS AND PLAN FOR SECOND ITERATION

In its first version, BIMERR RenoDSS enables the user to (i) calculate and visualize the energy, sustainability and economic KPIs of a given building configuration, (ii) set corresponding target KPIs, (iii) choose relevant renovation measures from a list of pre-configured renovation measures, (iv) automatically generate renovation scenarios which meet the target KPIs and are based on the chosen renovation measures, and (v) select the most suitable renovation scenario by sorting, filtering, and comparing their KPIs.

The following extensions are planned for the second release of BIMERR RenoDSS:

- More detailed information on single renovation measures within the scenario view. E.g., investment cost and quantity such as pieces, m^2 or m^3 of each measure.
- Enabling the user to select the currency for monetary units per renovation project.
- Providing PDF reports with detailed information on selected renovation scenarios to the user.
- Providing a downloadable IFC file for each renovation scenarios to the user.
- Visualizing the current building and renovated building configuration based on the corresponding IFC files (based on third-party libraries).
- Context-aware online user manual which describes the RenoDSS functionality within each view.
- Internationalization to support multiple languages within the user interface.

5. REFERENCES

Aliakbar Kamari, Carl Peter Leslie Schultz, Poul Henning Kirkegaard. (2019). Constraint-based renovation design support through the renovation domain model, Automation in Construction, Vol. 104, Pages 265-280.

Anne N. Nielsen, Rasmus L. Jensen, Tine S. Larsen, Søren B. Nissen (2016). Early stage decision support for sustainable building renovation – A review, Building and Environment, Volume 103, Pages 165-181.

Jalaei, Farzad & Jrade, Ahmad & Nassiri, M.. (2015). Integrating decision support system (DSS) and building information modeling (BIM) to optimize the selection of sustainable building components. Journal of Information Technology in Construction (ITcon)20. 399-420.

D3.1 “Stakeholder requirements for the BIMERR system”: the business scenarios, use cases, and system requirements described in D3.1 are the basis for the development of BIMERR RenoDSS.

D3.3 “BIMERR evaluation methodology”: energy, economic and sustainability KPIs described in D3.3 are calculated by the RenoDSS modules (LCA/LCC, energy, and urban planning).

D3.6 “BIMERR system architecture final version”: the final version of the BIMERR architecture provided an overview on the BIMERR components, how they communicate to each other and how BIMERR RenoDSS is embedded in the BIMERR Framework.

D4.6 “Building Information Query Builder Creation”: the query examples collected in context of T4.6 supported the design of the endpoint methods with which BIMERR users and components can retrieve data from the BIMERR Material and Component Database.

D4.8 “Integrated Interoperability Framework 1”: supported the preparation of RenoDSS for the future integration into the BIMERR interoperability framework.

D7.1 “Populated Material/Component Databases 1”: the developed building material and component database is used to provide RenoDSS with material and component data for the energy, economic, and sustainability KPI calculation.

D7.3 “Life Cycle Cost/Assessment Module 1”: the LCA module calculates the economic and sustainability KPIs of the renovation scenarios.

D7.5 “Building Energy Modeling Module 1”: the building energy performance module calculates the energy KPIs of the renovation scenarios.

D7.7 “Urban Planning Module 1”: the urban planning module calculates the urban planning KPIs of the renovation scenarios.

6. ANNEX: RENODSS-BEP COMMUNICATION


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                                        "Timestamp": "11/30 24:00:00"
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                                {
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                        "KPI_Units": "kWh.m^2.year",
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                        "KPI_Name": "Energy generated on site and exported to the district",
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}
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