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DELIVERABLE D7.10
Integrated BIMERR Renovation Decision Support System 2

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ACRONYMS

Acronym	Meaning
BEP	Building Energy Performance
BIF	BIMERR Interoperability Framework
BIM	Building Information Modeling
BIP	BIMERR Identity Provider
BIMERR	BIM-based holistic tools for Energy-driven Renovation of existing Residences
DSS	Decision Support System
EPW	EnergyPlus Weather Format
IFC	Industry Foundation Classes
JWT	JSON Web Tokens
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
M2M	Machine to Machine
MU	Monetary Unit
obXML	Occupant Behavior - XML Schema
PuK	Public Key
PV	Photovoltaics
RenoDSS	BIMERR Renovation Decision Support System
UI	User Interface
XML	Extensible Markup Language

EXECUTIVE SUMMARY

This document describes the BIMERR Deliverable D7.10 “Integrated BIMERR Renovation Decision Support System 2” and concludes the second 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 the second release of BIMERR RenoDSS we 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) PDF reports with detailed information on selected renovation scenarios, (iii) a downloadable IFC file for each renovation scenario, (iv) methods to extend the IFC files with property sets (psets) regarding materials/components, (v) connection of RenoDSS to the BIMERR identity provider, and (vi) integration of RenoDSS with other BIMERR applications via the BIMERR Interoperability Framework.

BIMERR RenoDSS is based on state-of-the-art technologies and consists of 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.

1. MOTIVATION AND 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 BIM-based renovation configurator that allows the user to explore alternative renovation interventions. For each renovation scenario, RenoDSS calculates economic, sustainability, energy, and comfort KPIs. The KPIs are calculated by BIM-based engines developed within BIMERR and using the state-of-the-art simulation engine EnergyPlus. The main advantage of the BIM-based approach is the efficient and fast generation of potential renovation scenarios, providing KPIs and IFC representation for each scenario, enabling the user to identify the most promising renovation scenarios, and fine-tune them in their favorite BIM software by building on the provided renovation scenario IFC files.

As described in BIMERR Deliverable D7.9 "Integrated BIMERR Renovation Decision Support System 1", 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. The RenoDSS software architecture is modularized and open to external components (e.g., BIMERR Interoperability Framework). 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 the accuracy of estimations and projections compared to existing approaches such as energy performance certificate software.

1.1 SCOPE AND OBJECTIVES OF THE DELIVERABLE

D7.10 "Integrated BIMERR Renovation Decision Support System 2" 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 second version of BIMERR RenoDSS.

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

- Functionalities of BIMERR RenoDSS,
- Technology stack,
- Communication with BIMERR RenoDSS modules,
- Improvements introduced in the second release of BIMERR RenoDSS,
- Assumptions and restrictions of the second release,
- Installation instructions,
- Licensing, and
- Usage walkthroughs

1.2 RELATION TO OTHER TASKS/DELIVERABLES

T7.5 "Decision support system engine and UI integration" and therefore D7.10 "Integrated BIMERR Renovation Decision Support System 2" are related to the following BIMERR deliverables:

- 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.
- D3.6 "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.
- D4.5 "BIMERR Building Semantic Modelling tool 2" used for the BIF integration of RenoDSS

- D4.7 “BIMERR Information Collection & Enrichment Tool 2” used for the BIF integration of RenoDSS
- D4.9 “Integrated Interoperability Framework 2” for integrating RenoDSS into the BIMERR Interoperability Framework (BIF)
- D7.2 “Populated Material/ Component Databases 2” provides building material and component data to RenoDSS.
- D7.4 “Life Cycle Cost/ Assessment Module 2” provides LCA/LCC KPI calculation services to RenoDSS.
- D7.6 “Building Energy WP7 Modeling Module 2” provides energy KPI calculation services to RenoDSS.
- D7.8 “Urban Planning Module WP7 2” provides urban planning KPI calculation services to RenoDSS.
- D7.9 “Integrated BIMERR Renovation Decision Support System 1” is the basis for the extensions and improvements developed within the second RenoDSS development iteration.
- T8.1 “External information availability and sourcing”: ensures that data relevant for pre-validation and validation sites are available.

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.

BIMERR RenoDSS is available at[1]: 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.

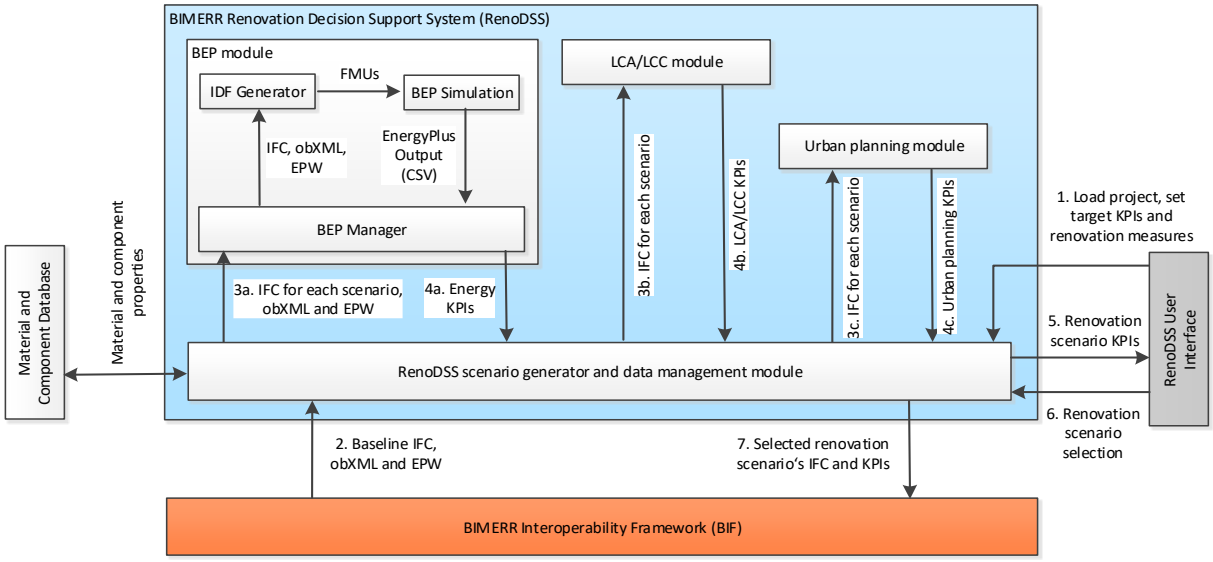

Figure 1: architecture of the BIMERR renovation support tools

[1] Please send an email to support@xylem-technologies.com to request access credentials.

RenoDSS communicates via the RenoDSS Data Management Module with the LCA/LCC module, BEP (Building Energy Performance) module, Urban Planning module, RenoDSS UI, BIMERR Material and Component Database, and BIMERR Interoperability Framework:

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) and obXML (occupant behaviour model) files for the selected renovation project from the BIMERR Interoperability Framework (BIF). 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 BIMERR Deliverable D7.9 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 module. To the BEP module, it also sends the obXML previously retrieved from the BIF and the EPW file retrieved from the urban planning module.
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.

2.3 TECHNOLOGY STACK AND IMPLEMENTATION TOOLS

BIMERR RenoDSS is based on state-of-the-art technologies and consists of 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, which is written in Java and generates renovation scenarios based on the current building configuration and potential renovation measures selected and configured by the user.
- The Data Layer that utilizes PostgreSQL to store global and project-specific renovation measures, potential renovation scenarios and their KPIs.

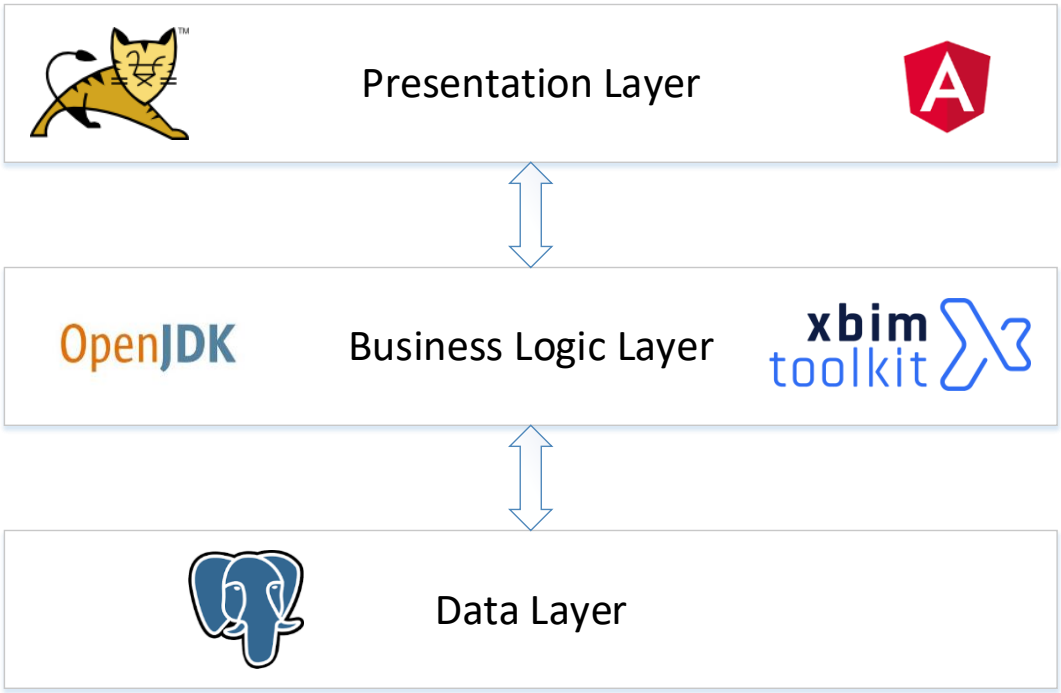

Figure 2: architecture of BIMERR RenoDSS

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

Table 1: 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)

In the following sections we describe the functionalities which were developed and released in the second BIMERR RenoDSS development iteration.

2.4 CHANGES INTRODUCED IN THE SECOND RENODSS RELEASE

2.4.1 Detailed renovation scenario information

The scenario screen was enhanced with additional information about the KPI calculation. The first column shows a warning triangle if outdated files (e.g., IFC) were used for generating this scenario. On mouse over the user gets detailed information about the outdated file(s).

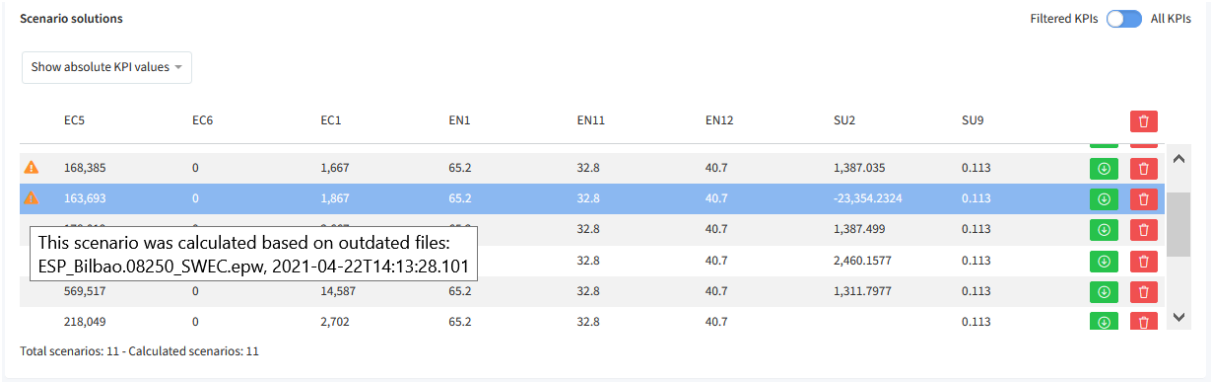

Figure 3: information about files used at scenario generation

When the user selects a scenario from the list, a detailed view of the measures applied in this scenario is shown. This view displays the quantity, life cycle cost and the environmental cost indicator for each measure as well as all existing, removed and newly applied material layers.

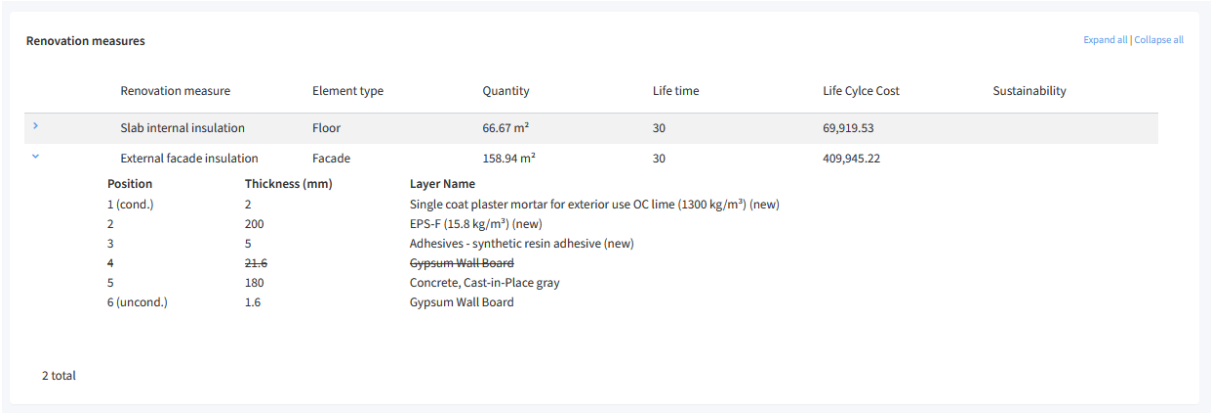

Figure 4: scenario renovation measure details

2.4.2 IFC file extension/enhancement

In deliverable D7.4 the user interface and mechanisms to extract data used for KPI calculation has been described. This part describes how the enriched data is written back to the IFC-File for further processing by other modules. Materials are enhanced with three different property sets of type IfcMaterialProperties[2]:

2.4.2.1 OPAQUE MATERIAL THERMAL PROPERTIES (OPAQUEMATERIALPROPERTIES):

Opaque Material Thermal Properties are defined per material in the IFC file. If a material has no value defined for one of the properties, the property is omitted in the IFC file. The user will be notified if certain KPIs cannot be calculated because of missing property values.

Property Name	Template	Value
Roughness	IfcPropertySingleValue	IfcText
Conductivity	IfcPropertySingleValue	IfcReal
Density	IfcPropertySingleValue	IfcReal
SpecificHeat	IfcPropertySingleValue	IfcReal
ThermalAbsorptance	IfcPropertySingleValue	IfcReal
SolarAbsorptance	IfcPropertySingleValue	IfcReal
VisibleAbsorptance	IfcPropertySingleValue	IfcReal

IFC file snippet:

```
#62021=IFCMATERIALPROPERTIES('OpaqueMaterialProperties',$,(#62022,#62023,#62024),#62019);
#62022=IFCPROPERTYSINGLEVALUE('SpecificHeat',$,IFCREAL(1000.),$);
#62023=IFCPROPERTYSINGLEVALUE('Conductivity',$,IFCREAL(0.49),$);
#62024=IFCPROPERTYSINGLEVALUE('Density',$,IFCREAL(1300.),$);
```

2 https://standards.buildingsmart.org/IFC/DEV/IFC4_2/FINAL/HTML/schema/ifcmaterialresource/lexical/ifcmaterialproperties.htm, last access: 09.03.2021

2.4.2.2 GLAZING CONSTRUCTION THERMAL PROPERTIES (PSET_GLAZINGMATERIALPROPERTIES):

Glazing Construction Thermal Properties are defined for each transparent building element type (window, glass door). If there is no value defined for one of the properties, the property is omitted in the IFC File. The user will be notified if certain KPIs cannot be calculated because of missing property values.

Property Name	Template	Value
Ufactor	IfcPropertySingleValue	IfcReal
SolarHeatGainCoefficient	IfcPropertySingleValue	IfcReal
VisibleTransmittance	IfcPropertySingleValue	IfcReal

IFC file snippet:

```
#61998=IFCMATERIALPROPERTIES('Pset_GlazingMaterialProperties',$,(#61999,#62000,
#62001),#5225);
#61999=IFCPROPERTYSINGLEVALUE('Ufactor',$,IFCREAL(0.001),$);
#62000=IFCPROPERTYSINGLEVALUE('SolarHeatGainCoefficient',$,IFCREAL(0.002),$);
#62001=IFCPROPERTYSINGLEVALUE('VisibleTransmittance',$,IFCREAL(0.003),$);
```

2.4.2.3 SUSTAINABILITY PROPERTIES

Sustainability properties are defined for each material or building element (such as windows, doors, heating elements, etc.). For properties defined for a material the according IfcMaterialProperties are named *SustainabilityMaterialProperties*. Otherwise, if the properties are defined based on a specific building element they are defined as IfcPropertySet[3] and named *Pset_SustainabilityProperties*.

If one of the values is missing for a specific component/material the property is omitted in the IFC File.

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3 https://standards.buildingsmart.org/IFC/DEV/IFC4_2/FINAL/HTML/schema/ifckernel/lexical/ifcpropertyset.htm, last access: 09.03.2021

Property Name	Template	Value
GWP	IfcPropertySingleValue	IfcReal
AP	IfcPropertySingleValue	IfcReal
ODP	IfcPropertySingleValue	IfcReal
POCP	IfcPropertySingleValue	IfcReal
ADPE	IfcPropertySingleValue	IfcReal
EP	IfcPropertySingleValue	IfcReal
ADPF	IfcPropertySingleValue	IfcReal

IFC File Snippet:

```
#62025=IFCMATERIALPROPERTIES('SustainabilityProperties',$,(#62026,#62027,#62028
,#62029,#62030),#62019);
#62026=IFCPROPERTYSINGLEVALUE('GWP',$,IFCREAL(0.178354),$);
#62027=IFCPROPERTYSINGLEVALUE('POCP',$,IFCREAL(3.521E-05),$);
#62028=IFCPROPERTYSINGLEVALUE('ODP',$,IFCREAL(1.E-08),$);
#62029=IFCPROPERTYSINGLEVALUE('EP',$,IFCREAL(0.00020386),$);
#62030=IFCPROPERTYSINGLEVALUE('AP',$,IFCREAL(0.000524),$);
```

2.4.2.4 COST PROPERTIES

Cost properties are defined for each material layer or building element (such as windows, doors, heating elements, etc.). For properties defined based on a material layer the according IfcMaterialProperties are named *CostMaterialProperties*. Otherwise, if the properties are defined based on a specific building element they are defined as IfcPropertySet[4] and named *Pset_CostProperties*.

4 https://standards.buildingsmart.org/IFC/DEV/IFC4_2/FINAL/HTML/schema/ifckernel/lexical/ifcpropertyset.htm, last access: 09.03.2021

If one of the values is missing for a specific component/material layer the property is omitted in the IFC File.

Property Name	Template	Value
MaterialCost	IfcPropertySingleValue	IfcReal
InstallationCost	IfcPropertySingleValue	IfcReal
MaintenanceCost	IfcPropertySingleValue	IfcReal
DisposalCost	IfcPropertySingleValue	IfcReal
InstallationYear	IfcPropertySingleValue	IfcReal
Lifetime	IfcPropertySingleValue	IfcReal

IFC File Snippet:

```
#62034=IFCMATERIALPROPERTIES('CostMaterialProperties',$,(#62035,#62036,#62037,
#62038,#62039),#62020);
#62035=IFCPROPERTYSINGLEVALUE('INSTALLATION_COST',$,IFCREAL(2.),$);
#62036=IFCPROPERTYSINGLEVALUE('MAINTENANCE_COST',$,IFCREAL(6.),$);
#62037=IFCPROPERTYSINGLEVALUE('DISPOSAL_COST',$,IFCREAL(3.),$);
#62038=IFCPROPERTYSINGLEVALUE('MATERIAL_COST',$,IFCREAL(2.),$);
#62039=IFCPROPERTYSINGLEVALUE('LIFETIME',$,IFCREAL(30.),$);
```

2.4.3 Renovation scenario IFC files

For each renovation scenario displayed in the scenario screen, the corresponding IFC file is available for downloading by using the green download button (see Figure 5).

Figure 5: IFC file download

2.4.4 PDF reports

Apart from the IFC file, for each scenario listed in the renovation scenario screen the user can download a PDF report, using the blue download button (see Figure 6), providing data about the selected scenario. Basic information about the renovation site – such as address, coordinates and floor area – as well as information about the scenario – such as renovation measures applied, removed/new/existing layers of each measure and all calculated KPIs – are available in the PDF report. A screenshot of a downloaded PDF report is displayed in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

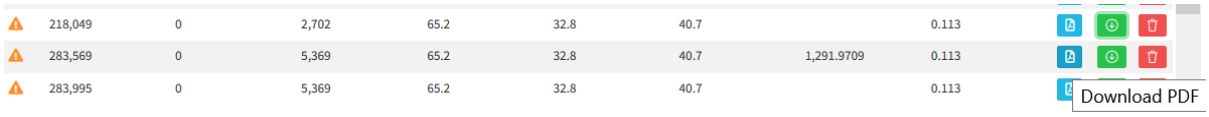

Figure 6: PDF file download

Address	Larrakoetxe Kalea, 1, 48004 Bilbao
Coordinates	43.26083195641566, - 2.898585185792794
Construction Year	1970
Floor area	132.73 m²

Date 25.06.2021

Scenario Details

Scenario: 8404fa3f-4a64-4b41-86d2-4e5b31644ff8

Renovation measure	Element type	Quantity	Lifetime in years	Lifecycle cost (MRU)	Sustainability (MRU)
External facade insulation	FACADE	158.94 m²	30	123997.37	

Layer

Position	Layer name	Layer type	Thickness
1	Single coat plaster mortar for exterior use OC lime (1300 kg/m³)	new	2 mm
2	Wood-wool board WWD magnesite-bonded (550 kg/m³)	new	100 mm
3	Adhesives - synthetic resin adhesive	new	5 mm
4	~~Gypsum Wall Board~~	removed	21.6 mm
5	Concrete, Cast-in-Place gray	existing	180 mm
6	Gypsum Wall Board	existing	1.6 mm

Identifier	Unit	Absolute	Absolute deviation	Percentage of baseline (in %)
EC1: Construction cost	monetary unit	2701.93		
EC2: Operation cost during period of analysis	monetary unit	69787.89	0	100
EC3: Maintenance cost during period of analysis	monetary unit	143034.82	74238.02	207.91
EC4: End of life cost	monetary unit	2098.38	425.96	125.47
EC5: Life cycle cost during period of analysis	monetary unit	217623.03	77365.92	155.16
EC6: Payback period	years	-0.03		
EC7: Return on Investment (ROI)	%	-3790.69		
EN1: Total primary energy consumption	kWh/m²/year	65.2	0	100
EN2: Total primary energy consumption non renewable	kWh/m²/year	65.2	0	100
EN3: Electric energy consumption	kWh/m²/year	65.2	0	100
EN7: Peak heating load	Watts	5700	0	100
EN9: Peak cooling load	Watts	6320.2	0	100
EN11: Heating energy demand	kWh/m²/year	32.8	0	100
EN12: Cooling energy demand	kWh/m²/year	40.7	0	100
EN14: Peak electricity load	Watts	7230	0	100
SU2: GWP100a total global warming potential	kg CO2-eq/m²	2460.16	1861.26	410.78
SU3: Acidification potential of soil and water (AP)	kg SO2-eq/m²	9.55	8.94	1577.59
SU4: Depletion potential of the stratospheric ozone layer (ODP)	kg CFC11-eq/m²	0.000089	0.000087	4482.78
SU6: Eutrophication potential (EP)	kg PO4-3-eq/m²	1.91	1.85	3408.15
SU8: Formation potential of tropospheric ozone (POCP)	(kg ethylene/m²)/m²	5.74	3.04	212.83
SU9: CO2 emission rate	kg CO2/m²	0.11	0	100
SU10: CO2 emissions reduction	%	-0.0000000000000025		

Figure 7: renovation scenario PDF report

2.4.5 Identity provider integration

RenoDSS supports the authentication/login of users either locally or by authentication at the BIMERR Identity Provider Service (BIP) (see Figure 8). The local authentication was kept for testing purposes and to enable the stand-alone usage of RenoDSS.

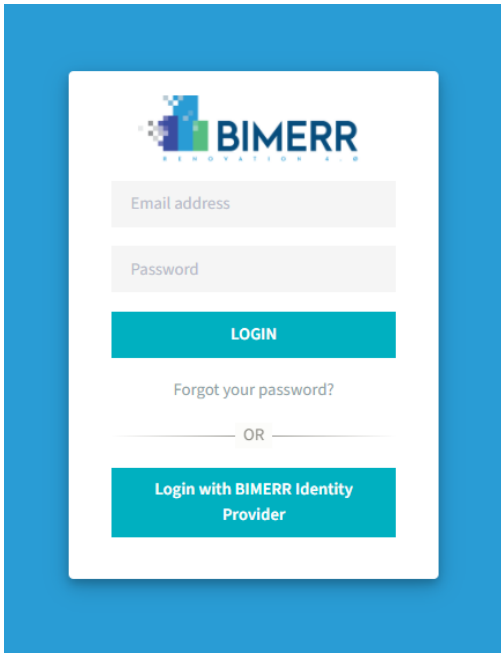

Figure 8: RenoDSS primary login page

Local authentication is executed by entering the username/password combination and authentication against the RenoDSS database. Upon successful authentication, two signed JSON Web Tokens (JWT), i.e., primary authentication token and secondary refresh token following the OAUTH approach are created to be used as authentication mechanism between the RenoDSS Single Page Application and the RenoDSS backend server. Upon manual logout, all involved user tokens are added to a blacklist that allows immediate invalidation of the tokens regardless of the expiration.

Login with the BIP redirects the user to the BIP login page where the user enters their username/password combination registered with BIP. This approach follows the Authorization code Grant pattern relying on Keycloak as the OpenID Connect Provider.

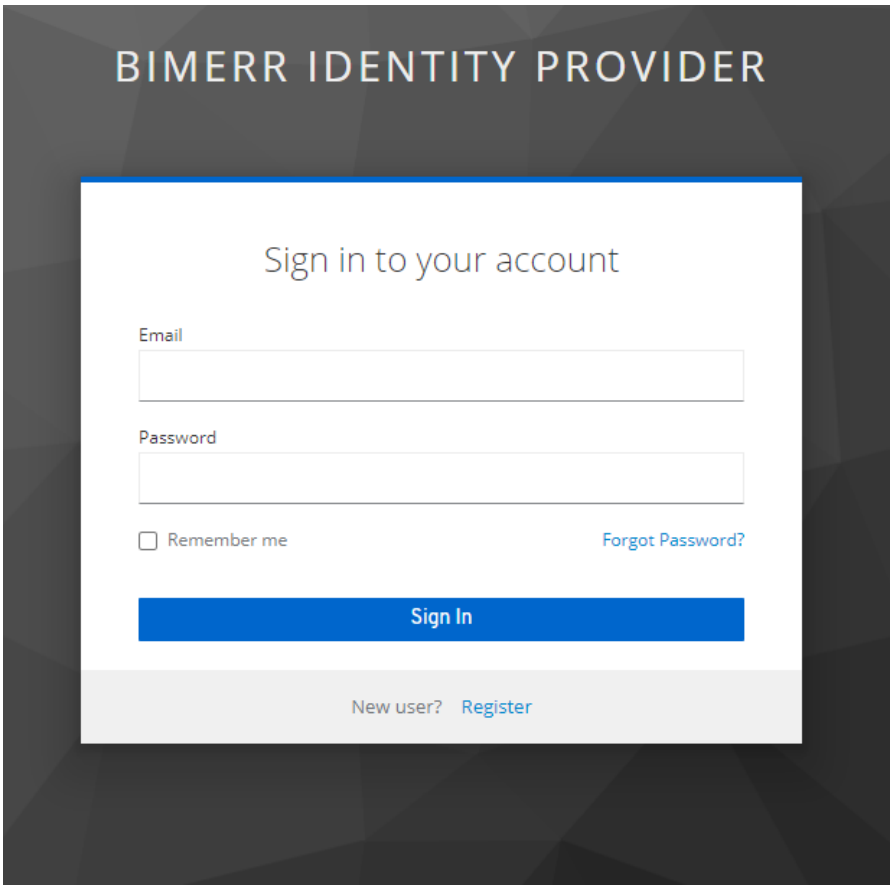

Figure 9: BIMERR identity provider login

Upon validation of the user's username/password combination, the BIP redirects the user back to the RenoDSS, where the authentication code is extracted from the redirect URI and automatically sent to the RenoDSS backend, where the ID, access and refresh tokens are retrieved from the BIP. Snippet of code showing the HTTP request is sent to the BIP to request new BIP tokens including the temporary session code and the redirect URL:

```
public BimerrIpTokenSet retrieveBimerrIpTokens(BipLoginCredentialsDto code) throws
IOException, InterruptedException {

     HttpClient client =
HttpClient.newBuilder().version(HttpClient.Version.HTTP_2).build();

        String requestBody = "grant_type=authorization_code&client_id=bimerr-
client&code=" + code.getCode() + "&redirect_uri=" + code.getRedirectUrl();

     HttpRequest request = HttpRequest.newBuilder()
```

```
            .uri(URI.create(BimerrConstants.BIMERR_IP_URL_TOKEN))

            .header(HttpHeaders.CONTENT_TYPE,
MediaType.APPLICATION_FORM_URLENCODED_VALUE)

            .POST(HttpRequest.BodyPublishers.ofString(requestBody)).build();

      HttpResponse<String> response = client.send(request,
HttpResponse.BodyHandlers.ofString());

      BimerrIpTokenSet set = null;

       if (StringUtils.isNotEmpty(response.body())) {

          set = new ObjectMapper().readValue(response.body(),
BimerrIpTokenSet.class);

       }

      return set;

   }
```

The ID token is used as primary authentication mechanism between the RenoDSS SPA[5] and the RenoDSS backend relying on the BIP public key for signature validation. Should the primary ID token be expired, the RenoDSS backend automatically tries to refresh the token using the refresh token provided by the BIP. When successful, the token set is replaced transparently so that no further actions are required by the user. When the refresh token has also expired, the user is logged out automatically. Furthermore, when the user logs out manually, the request is forwarded by the RenoDSS backend to the BIP to invalidate the tokens and the BIP user session. Authentication via BIP does not require the username/password to be stored in RenoDSS. In this case, RenoDSS does not acquire or store the username/password combination used in the BIP.

Upon login, RenoDSS identifies all relevant projects related to the logged-in user, i.e. all projects the user is authorized for. For local logins, this user-project mapping is evaluated using local database entries. For users authenticated via the BIP, the 'groups' claim in the ID token contain the projects the user is authorized for. In this case, the 'groups' are

[5] Single Page Application

extracted from the ID token (after validation with the BIP PuK), and the BIP queries for a complete list of groups using a Client Credentials Grant to extend the groups from the token with the group attributes. This operation is executed at the RenoDSS backend without interaction of the user relying on a M2M authorization scheme involving a machine client id and a pre-shared secret uniquely set for the RenoDSS service. Upon server-side authentication with the client grant, a short-term token is retrieved from the BIP to retrieve the attributes of the groups, i.e. project data. The project data is then synced with the RenoDSS database to allow for local use of the projects (including operations such as mapping with scenario details). This ensures that the project data is always synchronized when the user attempts to execute RenoDSS operations related to projects. A snippet of code showing the authentication procedure via BIP including the token retrieval and project synchronization is provided below:

```
public T authenticateUser(BipLoginCredentialsDto code) {

     try {

        BimerrIpTokenSet tokens = bimerrIpM2MService.retrieveBimerrIpTokens(code);

        // extract username

        String username =
bimerrTokenUtils.extractUsernameFromToken(tokens.getIdToken(), false);

        // add tokens to cache

        bimerrIpTokenCache.setTokens(username, tokens);

        // create temp bimerr user

        BimerrUser user = bimerrUserService.getBimerrIpUser(username);

        // add transient fields

        user.setToken(tokens.getIdToken());

        user.setRefreshToken(tokens.getRefreshToken());

        // get/update projects from BIMERR IP

        List<String> groups =
bimerrTokenUtils.extractGroupsFromToken(tokens.getIdToken());

        user.setBipProjectNames(groups);
```

```
        globalProjectService.syncBimerrIpProjects(groups);



        // return user

        return (T)user;

    }

    catch (Exception e) {

        throw new JwtAuthenticationException("Authentication via BIMERR IP
failed", e);

    }

  }
```

The project data is the forwarded to the RenoDSS SPA to be available for further actions. The project list includes both all local projects (when BIP users are granted access) as well as BIMERR projects provided by BIP. A screenshot of projects after login with BIP showing the local projects (copies for demonstration purposes) and the projects retrieved from BIP marked as BIMERR projects the current user is authorized is shown in Figure 10.

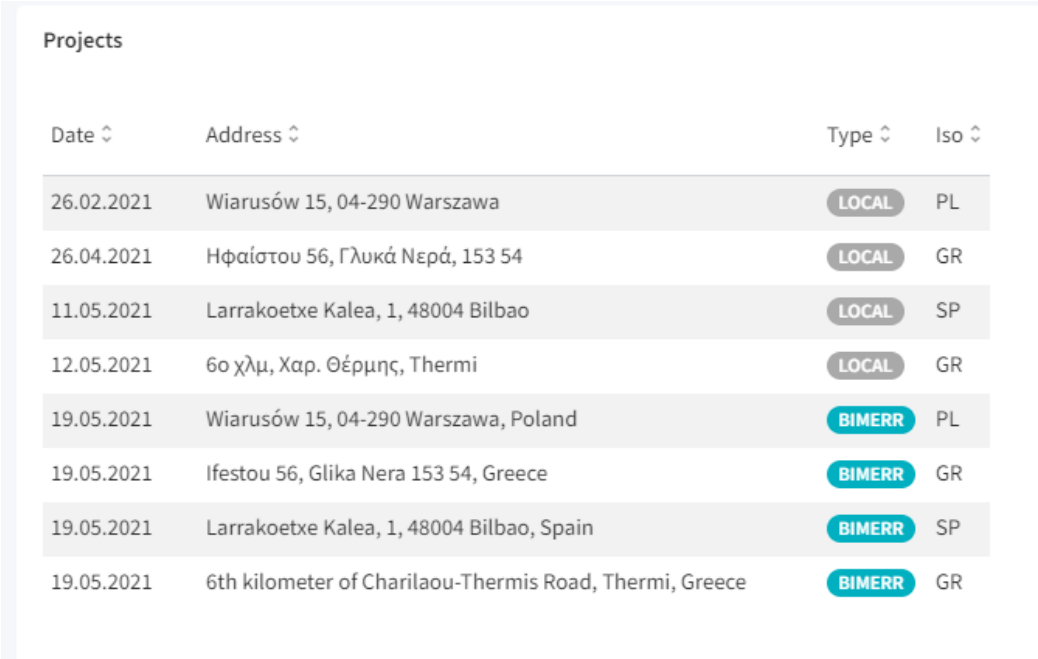

Figure 10: RenoDSS project list

2.4.6 Integration with BIMERR Interoperability Framework (BIF)

RenoDSS is integrated with the BIMERR Interoperability Framework (BIF) at two points:

- Retrieving baseline IFC and obXML files for projects that have been initiated by the BIMERR Identity Provider.
- Uploading renovation scenario KPIs and the corresponding IFC file to make it accessible for other BIMERR applications.

While full integration with BIF is part of WP8 activities, this section describes the current RenoDSS/BIF integration status with regards to the renovation scenario KPIs upload performed during the RenoDSS/BIF integration activities in collaboration with WP4.

After the user has selected appropriate renovation measures, RenoDSS generates potential renovation scenarios' IFC files and calculates the KPIs for each scenario. All the generated renovation scenarios' IFC files and KPIs are stored in the RenoDSS database and file system for later usage.

A cron job[6] which runs periodically on the RenoDSS server, checks if renovation scenarios exist which have not been uploaded to BIF yet. Stored scenarios are queried by the project ID through a GET request:

https://bimerr.s5labs.eu/api/query/3e42ba24-bfb5-4592-a4d9-01de7c526ed1?Scenario.relatedProject.Identifier=abc

To upload new renovation scenarios to the BIF, a POST request is sent to:

https://bimerr.s5labs.eu/api/upload/436fab31-06e3-42b0-a82d-e678d949f34b

[6] Time-based job scheduler in computer systems

The KPIs are encoded in JSON format within the POST body, the IFC file is encoded as Base64Binary within the field _uploaded_file (please note that the following POST body was shortened to enhance readability):


```
[
    {
        "projectId": "248",
        "scenarioId": "1f4f8e3d-2129-4d60-914b-9f0f49133504",
        "created": "2021-05-20T08:30:50",
        "kpis": [
            {
                "name": "EC1",
                "unit": "monetary unit",
                "description": "Construction cost",
                "values": [
                    {
                        "absoluteValue": 2666.7024383999998,
                        "timestamp": "2021-05-11T09:19:52"
                    }
                ]
            },
            .....
            {
                "name": "SU9",
                "unit": "kg CO2/m²",
                "description": "CO2 emission rate",
                "values": [
                    {
                        "absoluteValue": 0.11297747624981708,
                        "timestamp": "2021-05-11T09:21:02"
                    }
                ]
            }
        ],
        "measures": [
            {
                "name": "FLOOR: Slab internal insulation",
                "quantity": 66.66756095999999,
                "unit": "m²",
                "elements": [
                    {
                        "globalId": "2jVafIWKHA0BsSt8j0Hr$_",
                        "name": "Basic Roof:RoofExt:196238",
                        "type": "IfcSlab",
                        "area": 66.66756095999999,
                        "slabType": "ROOF"
                    }
                ],
                "layer": [
                    {
                        "name": "Rigid insulation",
                        "type": "existing",
                        "thickness": 100,
                        "unit": "mm",
                        "position": 1,
                        "layerCost": [
                            {
                                "name": "INSTALLATION_COST",
                                "value": 1,
                                "unit": "EUR"
                            },
                            {
                                "name": "DISPOSAL_COST",
                                "value": 1,
```

```
                        "unit": "EUR"
                    },
                    {
                        "name": "MAINTENANCE_COST",
                        "value": 0.05,
                        "unit": "EUR"
                    },
                    {
                        "name": "INSTALLATION_YEAR",
                        "value": 1970,
                        "unit": "EUR"
                    },
                    {
                        "name": "LIFETIME",
                        "value": 30,
                        "unit": "EUR"
                    },
                    {
                        "name": "MATERIAL_COST",
                        "value": 1,
                        "unit": "EUR"
                    }
                ]
            },
            .....
            {
                "name": "Aluminium bitumen sealing membrane",
                "type": "added",
                "thickness": 4,
                "unit": "mm",
                "position": 3
            },
            {
                "name": "XPS-G 30 80 to 100 mm (32 kg/m³)",
                "type": "added",
                "thickness": 100,
                "unit": "mm",
                "position": 4
            }
        ],
        "kpis": [
            {
                "name": "EC1",
                "unit": "monetary unit",
                "description": "Construction cost",
                "values": [
                    {
                        "absoluteValue": 2666.7024383999998,
                        "timestamp": "2021-05-11T09:19:53"
                    }
                ]
            },
            .....
            {
                "name": "SU8",
                "unit": "(kg ethylene/m²)/m²",
                "description": "Formation potential of tropospheric ozone (POCP)",
                "values": [
                    {
                        "absoluteValue": 0.0022720107954545458,
                        "timestamp": "2021-05-11T09:19:53"
                    }
                ]
            }
        ]
    }
],
"_uploaded_file": Base64BinaryString
```

```
    }
]
```

2.5 API DOCUMENTATION

Two REST endpoints are provided to extract information about renovation scenarios. Those are available at:

https://renodss.xylem-technologies.com/api/m2m/common/renovationscenarios/*

where the individual endpoints can be accessed as follows:

GET /api/m2m/common/renovationscenarios/*projectId*	Returns a list of all renovation scenarios for this project. Only basic information is provided (id, Scenario KPI Values, measures applied), e.g. /api/m2m/common/renovationscenarios/248
GET /api/m2m/common/renovationscenarios/details/*scenariold*	Returns a single scenario with all detailed information (scenario KPI values, measures, measure KPI values, affected IFC-elements, layers, layer cost), e.g. api/m2m/common/renovationscenarios/details/8bbd4fc6-5002-4398-ade7-feb000eef328

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.

If the API key is not provided correctly, the endpoints return 401 or 403 status. A JSON structure snippet for basic scenario information is shown below:

```
{
    "projectId": "248",
    "scenarios": [
        {
            "scenarioId":"37edee52-663b-4ebf-8925-26b05f57fdaa",
            "kpis": [
```

[7] https://www.postman.com/, last access: 02.02.2021

```
            {
                "name": "EC3",
                "unit": "monetary unit",
                "description": "Maintenance cost during period of analysis",
                "values": [
                    {
                        "absoluteValue": 417847.4933435227,
                        "absoluteDeviation": 377234.70428400978,
                        "percent": 1028.856926647465408815,
                        "timestamp": "2021-04-13T12:09:29.230"
                    }
                ]
            },
            {
                "name": "SU2",
                "unit": "kg CO2-eq/m²",
                "description": "GWP100a total global warming potential",
                "values": [
                    {
                        "absoluteValue": 2479.98448810549,
                        "absoluteDeviation": 1864.3249927632773,
                        "percent": 402.817548802199045135,
                        "timestamp": "2021-04-13T12:09:29.230"
                    }
                ]
            },
            {
                "name": "SU10",
                "unit": "%",
                "description": "CO2 emissions reduction",
                "values": [
                    {
                        "absoluteValue": -0.00000000000000254,
                        "timestamp": "2021-04-13T12:12:31.385"
                    }
                ]
            }
        ],
        "measures": [
            {
                "name": "FLOOR: Basement ceiling insulation",
                "quantity": 246.60092192000002,
                "unit": "m²",
                "layer": [
                    {
                        "name": "Acoustic Ceiling Tile 24 x 24",
                        "type": "existing",
                        "thickness": 100.0,
```

```
                            "unit": "mm",
                            "position": 1
                        },
                        {
                            "name": "Concrete, Lightweight",
                            "type": "removed",
                            "thickness": 204.8,
                            "unit": "mm",
                            "position": 2
                        },
                        {
                            "name": "Glass wool MW(GW)-WL (18 kg/m³)",
                            "type": "added",
                            "thickness": 100.0,
                            "unit": "mm",
                            "position": 3
                        },
                        {
                            "name": "Wood fibre board (250 kg/m³)",
                            "type": "added",
                            "thickness": 4.0,
                            "unit": "mm",
                            "position": 4
                        }
                    ]
                },
                {…}
            ]
        },{…}
    ]
}
```


The JSON result for the detail request provides further information on measure-level, such as the IFC element types and global unique IDs affected by the applied renovation measure, KPIs calculated for the measure and information about the cost per layer in case of layered renovation measures (constructions) or the cost per component in case of component-wise renovation measures (e.g., windows, heating systems, etc.):


```
{
    "projectId": "248",
    "scenarioId":"37edee52-663b-4ebf-8925-26b05f57fdaa",
    "kpis": […],
    "measures": [
        {
```

```
            "name": "FLOOR: Basement ceiling insulation",
            "quantity": 246.60092192000002,
            "unit": "m²",
            "elements": [
                {
                    "globalId": "2v0UWxqbH41gdGtT5E4Rjq",
                    "name": "Floor:Case1-floor:193162",
                    "type": "IfcSlab",
                    "area": 117.01396096,
                    "slabType": "FLOOR"
                },
                {
                    "globalId": "1ePVfoWu9969NqC_VZUM0k",
                    "name": "Floor:Case1-floor:183849",
                    "type": "IfcSlab",
                    "area": 129.58696096,
                    "slabType": "FLOOR"
                }
            ],
            "layer": [
                {
                    "name": "Acoustic Ceiling Tile 24 x 24",
                    "type": "existing",
                    "thickness": 100.0,
                    "unit": "mm",
                    "position": 1,
                    "layerCost": [
                        {
                            "name": "INSTALLATION_COST",
                            "value": 1.0
                        },
                        {
                            "name": "DISPOSAL_COST",
                            "value": 1.0
                        },
                        {
                            "name": "MAINTENANCE_COST",
                            "value": 0.05
                        },
                        {
                            "name": "INSTALLATION_YEAR",
                            "value": 1970.0
                        },
                        {
                            "name": "LIFETIME",
                            "value": 50.0
                        },
                        {
```

```
                    "name": "MATERIAL_COST",
                    "value": 1.0
                }
            ]
        },
        {
            "name": "Concrete, Lightweight",
            "type": "removed",
            "thickness": 204.8,
            "unit": "mm",
            "position": 2,
            "layerCost": [
                {
                    "name": "INSTALLATION_COST",
                    "value": 1.0
                },
                {
                    "name": "DISPOSAL_COST",
                    "value": 1.0
                },
                {
                    "name": "MAINTENANCE_COST",
                    "value": 0.05
                },
                {
                    "name": "INSTALLATION_YEAR",
                    "value": 1970.0
                },
                {
                    "name": "LIFETIME",
                    "value": 100.0
                },
                {
                    "name": "MATERIAL_COST",
                    "value": 1.0
                }
            ]
        },
        {
            "name": "Glass wool MW(GW)-WL (18 kg/m³)",
            "type": "added",
            "thickness": 150.0,
            "unit": "mm",
            "position": 3,
            "layerCost": [
                {
                    "name": "INSTALLATION_COST",
                    "value": 5.0
```

```
                        },
                        {
                            "name": "DISPOSAL_COST",
                            "value": 7.0
                        },
                        {
                            "name": "MAINTENANCE_COST",
                            "value": 1.0
                        },
                        {
                            "name": "MATERIAL_COST",
                            "value": 17.0
                        },
                        {
                            "name": "LIFETIME",
                            "value": 50.0
                        }
                    ]
                },
                …
            ],
            "kpis": [
                {
                    "name": "CO1",
                    "unit": "",
                    "description": "Thermal comfort (heating)",
                    "values": [
                        {
                            "value": 12.0,
                            "timestamp": "2021-02-09T09:57:06.737494"
                        }
                    ]
                }
            ]
        }
    ]
}
```


2.6 ASSUMPTIONS AND RESTRICTIONS

The second release of BIMERR RenoDSS is based on the following assumptions/restrictions:

- IFC files include second level space boundaries.

- Material and component properties are described in the IFC file by the defined pset and attributes names.
- Only one renovation measure per renovated building element is applied in one renovation scenario. E.g., while external and internal insulation system can be applied to different walls in the building in one renovation scenario it is not possible to assign external AND internal insulation systems on ONE wall within ONE renovation scenario.

2.7 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.

2.8 LICENSING

As parts of RenoDSS are based on and integrated into the Xylem business intelligence platform it is a closed source component. All UI components and core business logic (e.g., user administration, security, etc.) are based on the Xylem business intelligence platform. The RenoDSS business logic developed in WP7 (e.g., KPI calculation, renovation scenario generation, etc.) is built on top and integrated into the Xylem business intelligence platform.

3. BIMERR RENODSS END-TO-END USAGE WALKTHROUGH

Figure 11 shows the RenoDSS login view. The user can login via the BIMERR identity provider or local RenoDSS user credentials.

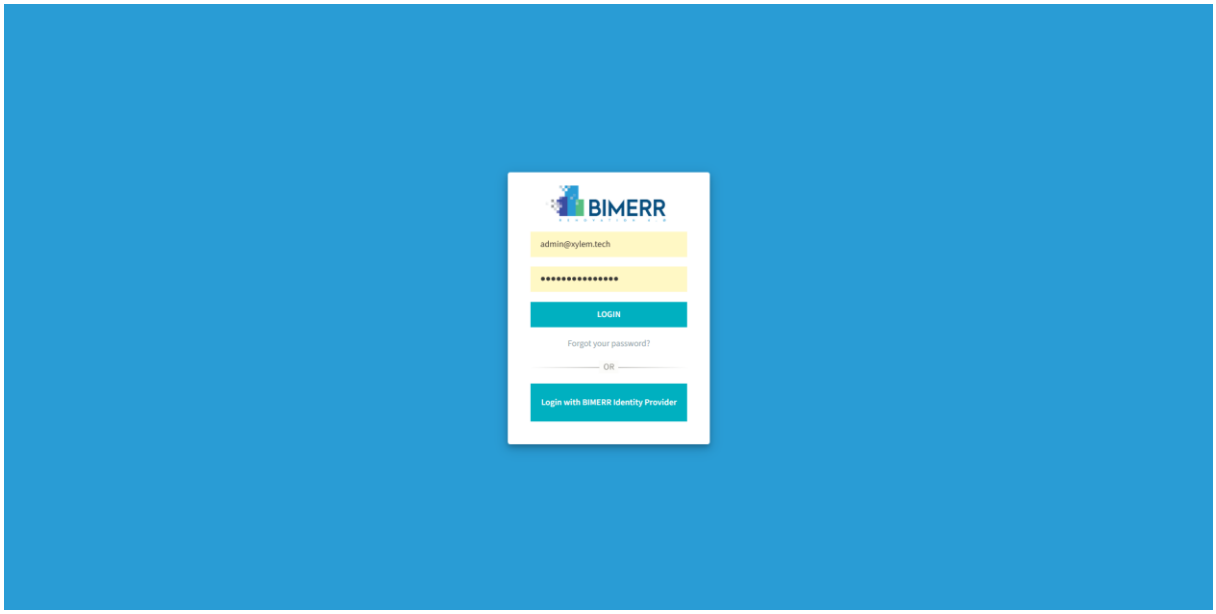

Figure 11: RenoDSS - login view

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. A label in the third column of the project list indicates the source of the project, and more precisely if the project has been loaded from the local RenoDSS (LOCAL) or the BIF (BIMERR).

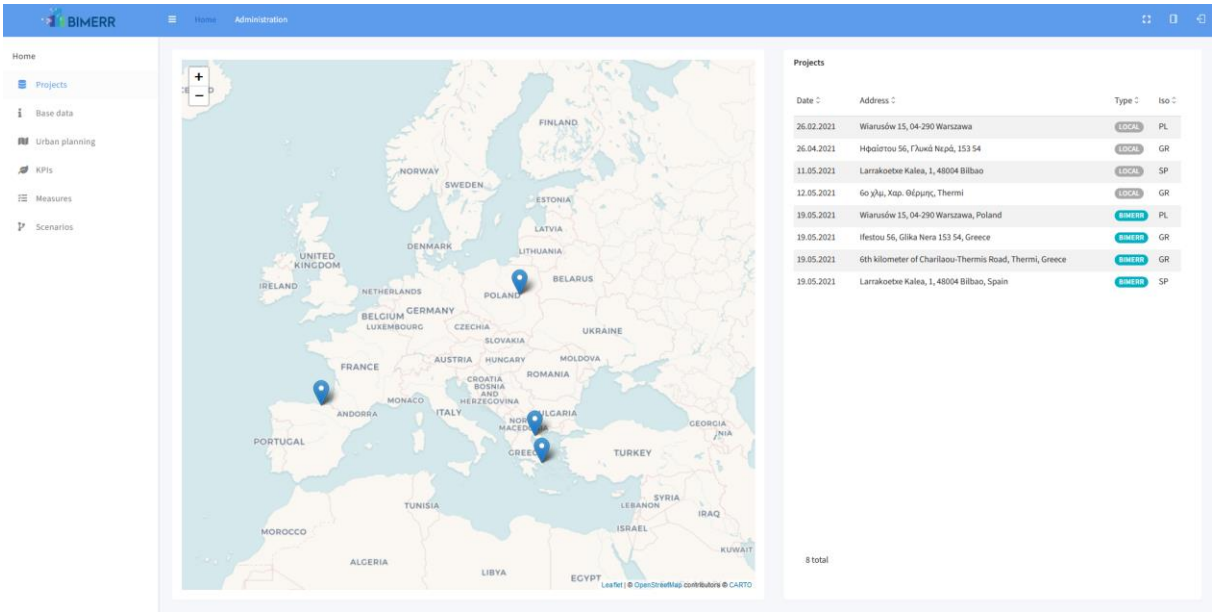

Figure 12: RenoDSS - project view

By clicking on a project in the list view, the base data of the project 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 (construction year and region). The building visualization provided in the top center area is based on the building's IFC file.

Input parameters for the LCA/LCC and energy performance module (see Deliverable D7.4 and Deliverable D7.6 for further details) are configured in the bottom area of the project view UI. Data for (i) material properties, (ii) analysis period and rates, (iii) energy prices and emissions, and (iv) 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.

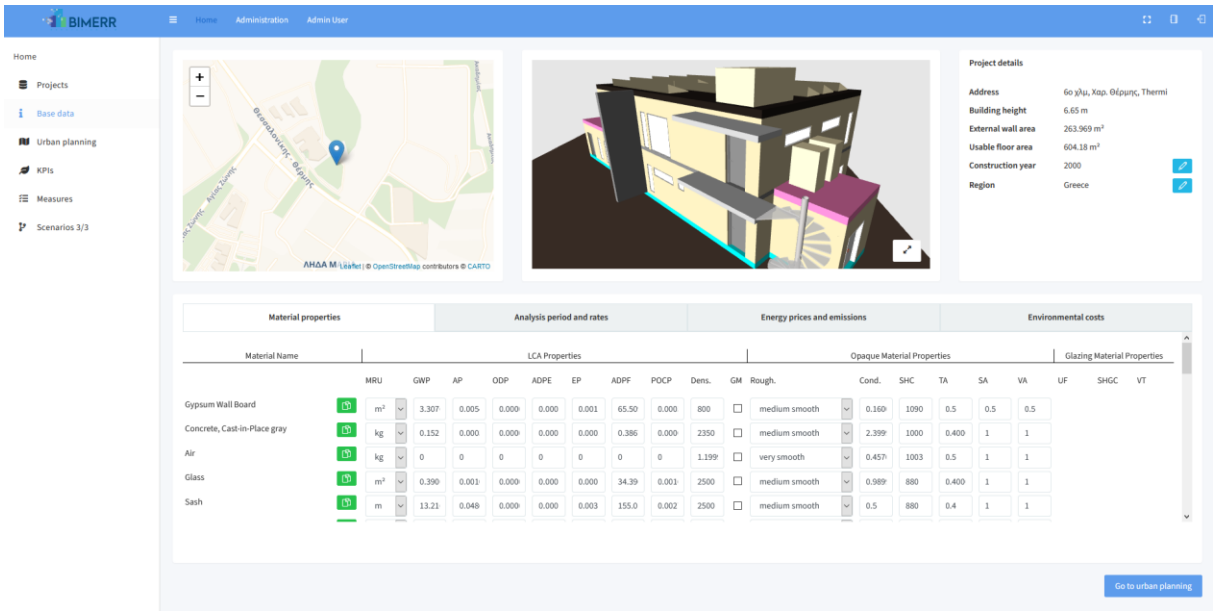

Figure 13: RenoDSS - base data view

Within the RenoDSS urban planning view (see Figure 14 and Deliverable D7.8 for further details) the user can add 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. Available energy networks are visualized on a separate layer if energy network data is available for this location. The shape and location of the building as well as information regarding energy networks can be downloaded in CityGML format.

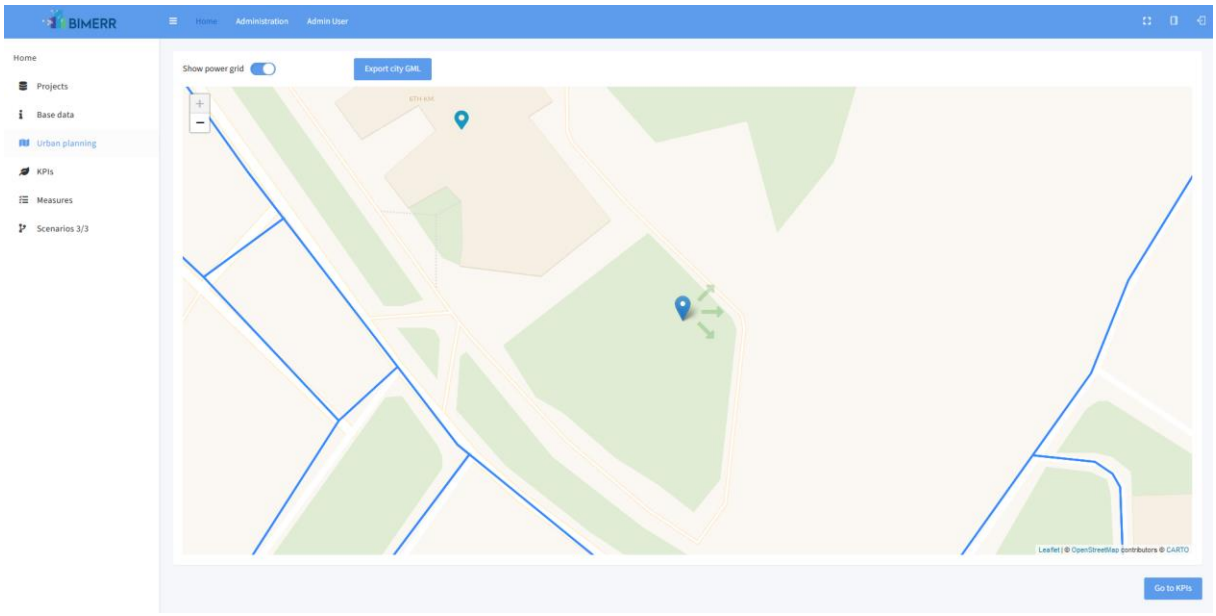

Figure 14: RenoDSS - urban planning view

Within the RenoDSS KPI view (see Figure 15), the KPIs calculated by the LCA/LCC module (see Deliverable D7.4), the Building Energy Performance module (see Deliverable D7.6), and the urban planning module (see Deliverable D7.8) are presented within the categories Economic, Sustainability, and Energy to the user. The calculated KPI is shown in column "Status quo", the target value can be set in column "Target". Within the renovation scenario view (see Figure 17) RenoDSS will only show renovation scenarios with KPIs that meet the target KPIs that have been set by the user.

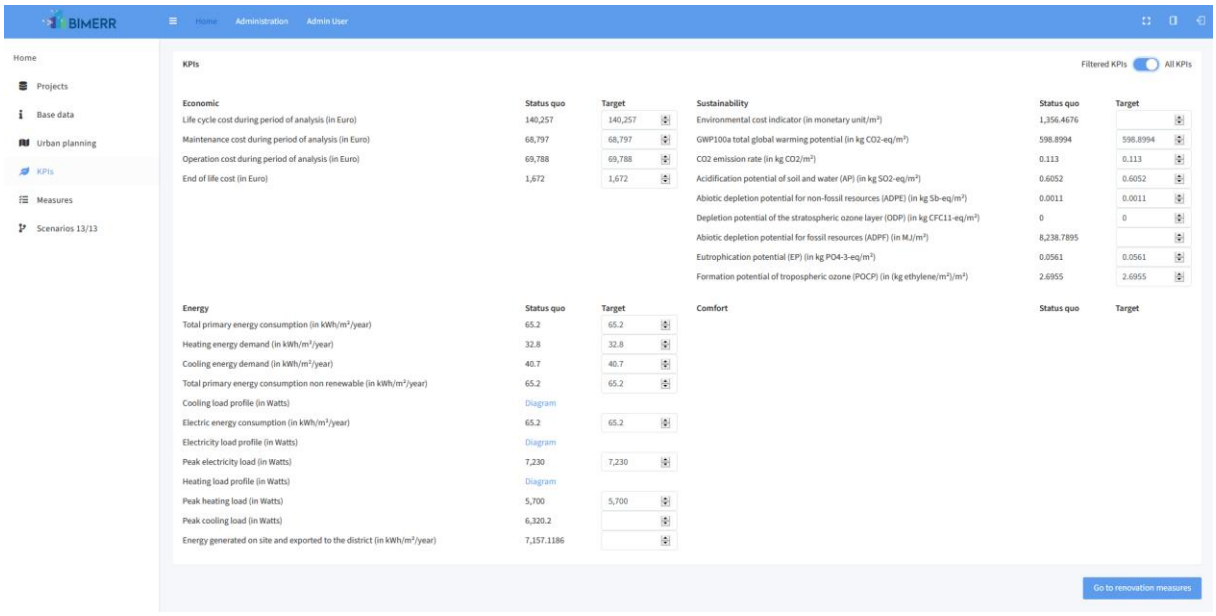

Figure 15: RenoDSS - KPI view

Within the renovation measure view (see Figure 16), the user selects renovation measures which are relevant for the building (available categories: façade, roof, floor, fenestration, heating system, hot water, solar collector, photovoltaic, cooling system). Please refer to Deliverable 7.9, Section 2.4 for further details on this process.

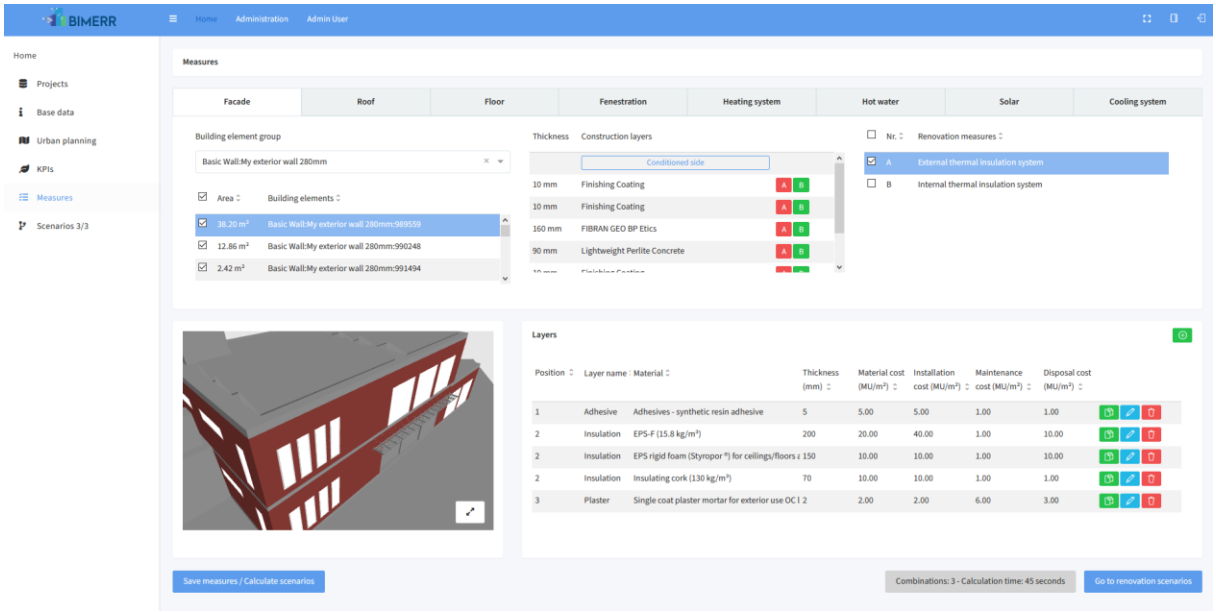

Figure 16: RenoDSS - renovation measure view

Within the renovation scenario view (see Figure 17), the results of the RenoDSS scenario generator (see Deliverable 7.9 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 center 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 right 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 center area. The visualization in the bottom right area colors the building elements which are affected by the selected renovation scenario in red.

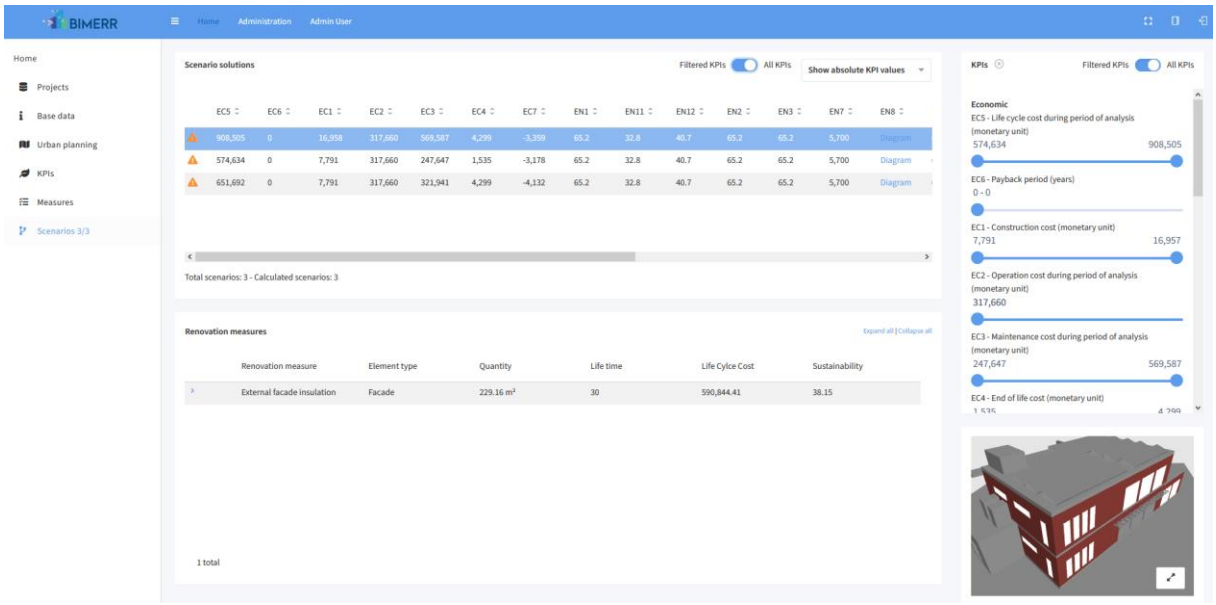

Figure 17: RenoDSS - renovation scenario view

4. CONCLUSIONS

In its second version, BIMERR RenoDSS provides the user with: (i) energy, sustainability and economic KPIs of a given building configuration, (ii) pre-configured renovation measures, (iii) the automated generation of renovation scenarios which meet the target KPIs and are based on the chosen renovation measures, (iv) renovation scenario KPI sorting, filtering, and comparison, (v) 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, (vi) PDF reports with detailed information on selected renovation scenarios, (vii) a downloadable IFC file for each renovation scenario, (viii) methods to extend the IFC files with property sets (psets) regarding materials/components, (ix) connection of RenoDSS to the BIMERR Identity Provider, and (x) integration of RenoDSS with other BIMERR applications via the BIMERR Interoperability Framework.

5. REFERENCES

[1] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en, last access: 16.11.2020

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