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DELIVERABLE D7.2
Populated Material/Component Database 2

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ACRONYMS

Acronym	Meaning
API	Application Programming Interface
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BIF	BIMERR Interoperability Framework
BIMERR	BIM-based holistic tools for Energy-driven Renovation of existing Residences
COP	Coefficient of performance
DB	Database
GUID	Global Unique Identifier
JSON	JavaScript Object Notation
LCA	Life Cycle Analysis
REST	Representational State Transfer

EXECUTIVE SUMMARY

This document describes the BIMERR Deliverable D7.2 “Populated Material/Component Database 2” demonstrator and concludes the final iteration of the development activities in T7.1 “Building Components Database Design & Development”. The BIMERR Material and Component Database is an integral part of the BIMERR framework as it provides technical, financial, and environmental impact data for building materials to BIMERR applications.

In the final release of the BIMERR Material and Component Database, we

- refactored the BIMERR material categories,
- developed a building material mapping approach which can be used to semi-automatically map similar building materials across different data sources and thereby enables the user to select the data sources which are used to populate the required building material property values in the context of a specific renovation project,
- developed an end user interface for managing existing and new building material data sources and building material categories, and
- developed an end user interface for manipulating building material and material mapping data.

The BIMERR Material and Component Database can be accessed via REST endpoint by other applications and the following data can be retrieved from the endpoint: (i) timestamp of the latest database update, (ii) full list of materials[1] without material details, (iii) full list of materials with material details, and (iv) material details of given material. The current database version provides data about 1.198 building materials originating from third party providers Baubook, Ökobaudat, and ASHRAE.

[1] In the remaining document the term material refers to both, material and component. This should enhance the readability of the document.

1. INTRODUCTION

Evaluating and selecting renovation options requires a quantified assessment of the different options in terms of cost, energy savings, comfort improvement, etc. The tools developed in BIMERR provide the necessary estimation and/or simulation engines. Their execution relies on information about the various materials that will be used/replaced during the renovation to properly estimate its impact. This information can be performance parameters (e.g., u-values for insulation materials, efficiency ratings like COP for heat pumps, etc.), cost parameters (e.g., purchase costs for the various materials, installation costs, depreciation, etc.), or LCA-related information (e.g., embodied energy, lifetime expectations, recyclability, etc.).

1.1 SCOPE AND OBJECTIVES OF THE DELIVERABLE

D7.2 "Populated Material/Component Database 2" reports the development activities in the context of Task T7.1 "Building Components Database Design & Development" of WP7 "Renovation Decision Support System". It documents the final version of the BIMERR Material and Component Database, which is responsible for providing technical, financial, and environmental impact data for building materials to BIMERR applications.

The objective of this document is to give an overview and documentation of the final release of the BIMERR Material and Component Database and describe:

- Functionalities of the BIMERR Material and Component Database
- Technology stack
- API which enables data exchange with BIMERR applications
- Assumptions and restrictions of the first and initial release of the database
- Installation instructions
- Usage walkthroughs to demonstrate how a user can add/modify building material information
- Licensing

1.2 RELATION TO OTHER TASKS/DELIVERABLES

T7.1 "Building Components Database Design & Development" and therefore D7.2 "Populated Material/Component Database 2" are related to the following BIMERR deliverables:

- D3.1 "Stakeholder requirements for the BIMERR system": the business scenarios, use cases, KPIs and system requirements described in D3.1 are the basis for the development of the BIMERR material and component database.
- 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 which components need access to the BIMERR Material and Component database.
- T4.6 "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.
- T7.2 "Renovation LCA/LCC Module", T7.3 "Building Energy Performance Modelling Module", T7.4 "Urban Planning Module", and T7.5 "Decision Support System Engine and UI" provide requirements in terms of data granularity and scope.
- T8.1 "External Information Availability and Sourcing": the results of T7.1 are required at T8.1 to provide validation and pre-validation sites with the required building material data.
- D9.2 "Report and associated material on BIMERR stakeholder engagement & training activities": D7.2 content will be used in D9.2 for describing the BIMERR Material and Component Database to potential end-users.

2. BIMERR MATERIAL AND COMPONENT DATABASE

2.1 OVERVIEW

The BIMERR Material and Component Database provides technical, financial, and environmental impact data of building materials to BIMERR components. The data is sourced from third party providers (technical and environmental impact data) and users (financial data). The BIMERR material data model harmonizes and integrates the data sources and provides a standardized data view for BIMERR applications. The following approach was followed for creating and extending the BIMERR building material and component database:

1. Development of building material classification tree which will be shared via endpoint to BIMERR applications.
2. Identification of third-party data sources which provided the data required by BIMERR applications (based on the results of the BIMERR requirements analysis).
3. Development of a BIMERR material data model which integrates the identified data sources.
4. Extraction of third-party data, normalization, and integration according to BIMERR material data model. This step includes the harmonization of the used units (m^3, kg, thickness, etc.).
5. Mapping the materials to the classification tree developed in Step 1.
6. Development of a building material mapping approach which can be used to semi-automatically map similar building materials across different data sources and thereby enables the user to select the data sources which are used to populate the required building material property values in the context of a specific renovation project.

The following data sources are currently used:

- Baubook for technical building material data: The web platform baubook[2] is a database of building material and their ecological and structural-physical aspects.

[2] www.baubook.info, last access: 11.05.2021

Currently 3.616 building products from 359 vendors are described in the database. The baubook platform also contains a catalogue with around 400 reference values which includes different ecological and structural-physical indicators. They are especially helpful for calculating energy certificates in early planning phase where the concrete products are not decided yet.

- Ökobaudat for environmental impact data: oekobaudat.de provides around 1.200 life cycle assessment datasets regarding building materials, construction, transport, energy and disposal processes. The database can be used to reconstruct the entire building life cycle and is maintained by the German Ministry of Interior, Building and Community. The used data format is based on the ILCD data format, compliant to DIN EN 15804[3] and provided as CSV files.
- ASHARE for technical building material data which is not provided by Baubook but required to run energy simulations with Energy Plus. The ASHRAE 2005 Handbook of Fundamentals, Chapter 25 contains thermal property data (e.g., conductivity, density, specific heat) of selected building materials. The data is provided for reference materials and not concrete building products. We included this data source in the BIMERR Material and Component Database, as it provides all data which is required to run the BIMERR RenoDSS building energy performance module and therefore complements Baubook on missing data (e.g., the roughness values provided by ASHRAE are not provided by Baubook but required to run the energy performance estimation module).
- User input for project-specific financial data

The BIMERR Material and Component Database is available at[4]: https://renodss.xylem-technologies.com/api/m2m/common/materials/*

The BIMERR Material and Component Database can be extended by additional data sources if needed.

[3] https://www.beuth.de/de/norm/din-en-15804/148775446, last access: 11.05.2021

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

2.2 ARCHITECTURE

Based on the BIMERR architecture (D3.6), Figure 1 shows the architecture of RenoDSS and its connection to the BIMERR Material and Component Database.

The main aim of RenoDSS is to put forward an intuitive and easy-to-use interface that illustrates the 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 will offer to the user a renovation configurator that will allow her to explore alternative renovation interventions.

RenoDSS communicates via the RenoDSS Data Management Module with the BIMERR Material and Component Database. The database provides an API on its endpoint and thereby enables external applications to retrieve material data.

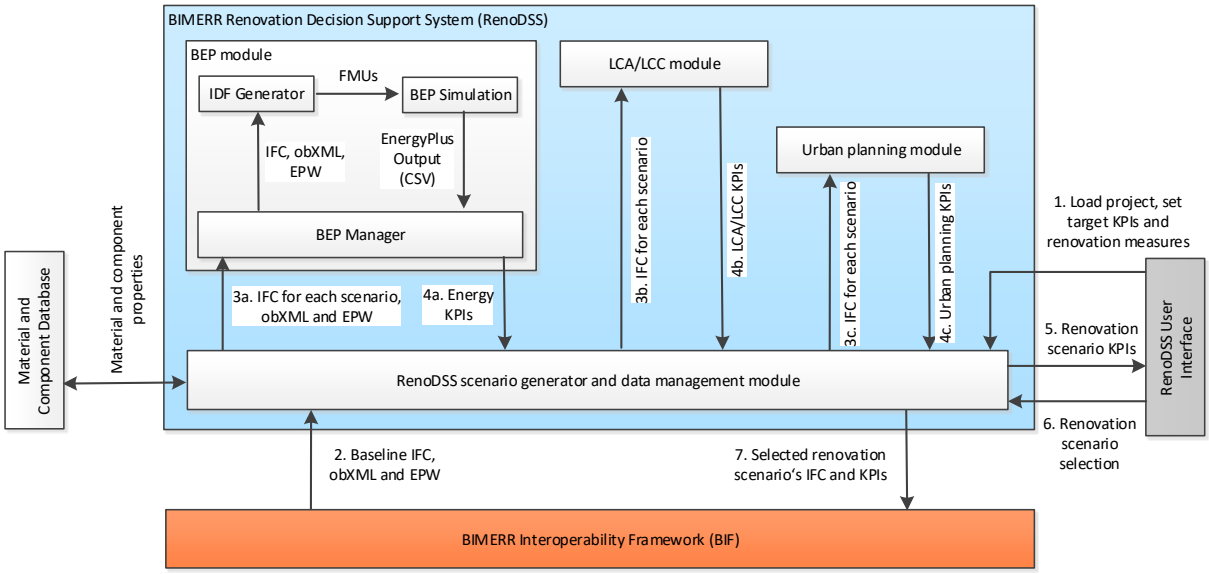

Figure 1: architecture of the BIMERR Material and Component Database

2.3 DATA MODEL

The data structure for the refactored material database is displayed in Figure 2. Materials are stored in tables *glb_material* (global materials) and *prj_material* (project specific materials). Each material can be categorized. Material categories (described in Section 2.4) are stored in table *glb_material_category* and referenced through mapping tables which map categories to global (*glb_material_category_map*) or project-specific materials (*prj_material_category_map*).

Each property of a material can be mapped to another material. These mappings (see Section 2.5 for project specific mappings and Section 2.7 for global material mappings) are stored in tables *prj_material_mapping* and *glb_material_mapping*. Each mapping has a reference to the material that the mapping is done for, the property that is mapped and the material this property is mapped to.

For each material property users associated with the admin role can define a property for finding similar materials (see Section 2.6). These category property mappings are stored in table *glb_category_property_map*.

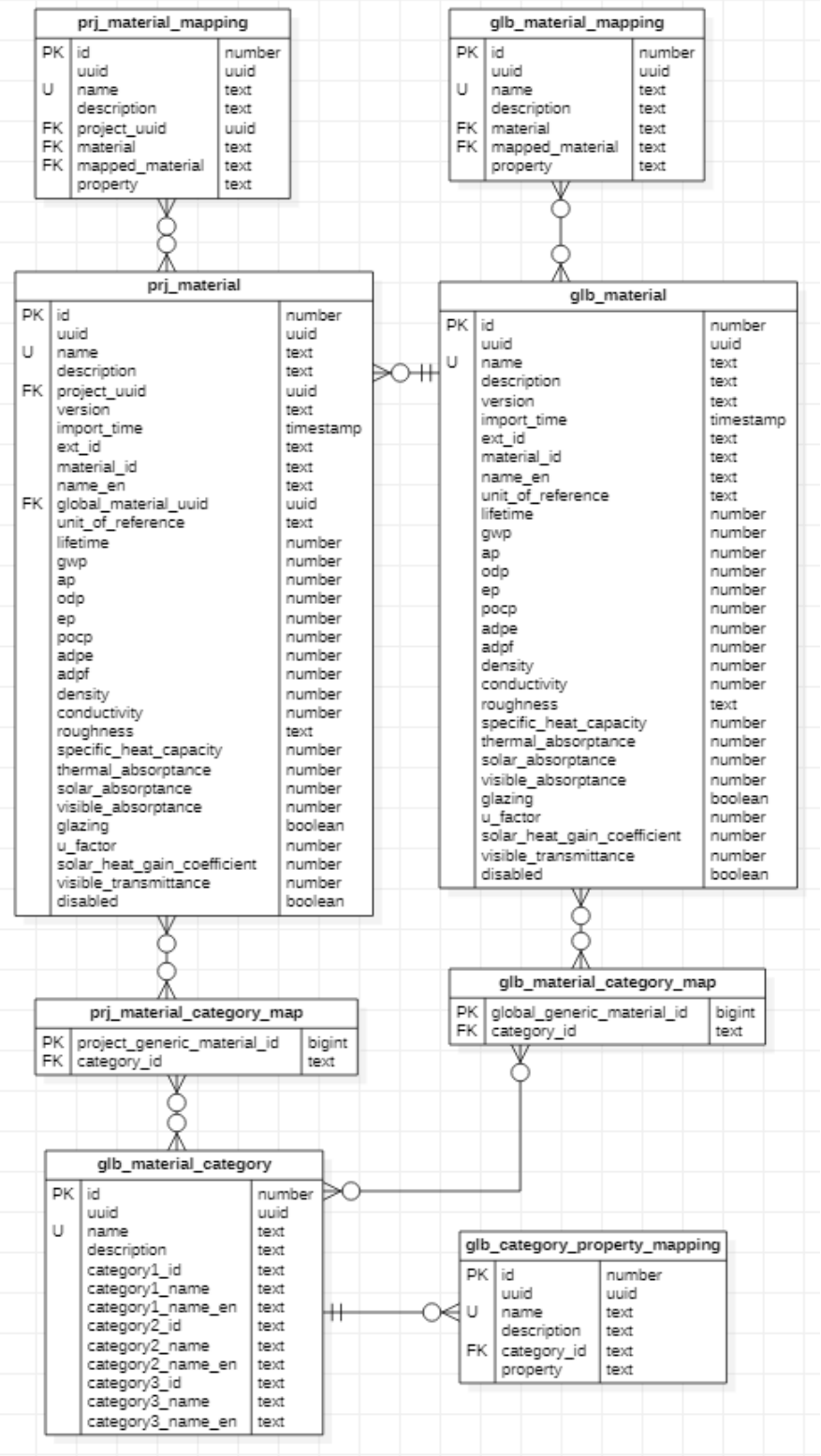

Figure 2: data model for material database

2.4 BIMERR MATERIAL CATEGORIES

This section outlines the refactored BIMERR material classification system. The main purpose of the material classification is to enable the user to efficiently find a given material and map different building material data sources. Please see Section 2.9 on how to download the categories in a machine-readable form via the developed API. Based on the learnings since the first database deployment, we refactored the material categories as follows:

- Adhesive and filler
- Air
    - Heat flow horizontal
    - Heat flow upwards
    - Heat flow downwards
- Building board
    - Fibre-cement board (interior)
    - Plasterboard
    - Wood, plywood, and wood-based panel
    - Clay building board
    - Sheets of bonded lightweight aggregate
    - Cement-bound lightweight concrete slab
- Building technology
    - Electrical installation
    - Heating system
        - Biomass boiler
        - Fossil boiler
        - Radiators/radiator
        - Heating pipe
        - Heat pump
    - Hot water tank
    - Photovoltaic system
    - Pipe material
    - Sanitary installation
    - Solar system
    - Ventilation system
        - Ventilation unit
        - Ventilation pipe
        - Accessories
- Ceiling and roof element
- Coating and impregnation
- Concrete
    - Concrete in WU quality
    - Concrete with pumice aggregate
    - Concrete with expanded shale aggregate

    - Concrete with expanded clay or brick chippings aggregate
    - Concrete with EPS aggregate
    - Concrete with slag pumice aggregate
    - Concrete with sulphate slag cement
    - Normal concrete
    - Reinforced concrete / normal concrete with reinforcement
- Constructive (solid) wood
- Door
- Facade cladding
- Fills and aggregate
- Floor covering and skirting board
    - Elastic floor covering
    - Solid floor covering of wood and other natural raw materials
    - Mineral floor covering
    - Textile floor covering
    - Underlays and back coating of floor covering
- Gas
- Insulation
    - Insulating material from renewable raw material
        - Cotton insulation material
        - Flax insulating material
        - Grass fibre insulation board
        - Hemp insulating material
        - Wood fibre insulating material
        - Wood shaving (loose), sawdust
        - Coconut fibre insulating material
        - Cork insulating material
        - Sheep wool insulation
        - Reed insulation panel
        - Straw insulation material
        - Cellulose fibre insulation material
    - Mineral insulation material
        - Glass wool insulating material
        - Wood chip insulation board
        - Wood wool insulation board
        - Wood-wool multi-layer insulation board
        - Mineral foam insulation board
        - Perlite insulation board
        - Foam glass insulation board
        - Rock wool insulation material
        - Vacuum insulation panel
    - Synthetic insulating material
        - EPS insulating material
        - Phenolic resin foam board
        - Polyester fibre insulating material
        - Polyethylene (PE) insulating material
        - PUR/PIR insulation board
        - XPS insulation board

        - Cement-bound EPS board
- Masonry
    - Concrete masonry
    - Sand-lime brickwork
    - Adobe masonry (unfired)
    - Natural stone masonry
    - Aerated concrete masonry
    - Brick masonry
        - Filling brick
        - High perforated brick masonry
        - Slotted brick masonry
- Mounting accessories / individual building material
- Natural stone
- Outdoor surfacing
    - Asphalt pavement
    - Floor covering capable of infiltration
- Plaster and mortar
    - External plaster
    - Adhesive bridges and pre-spray
    - Interior plaster
    - Mortar
    - Plaster base
- Roof covering
- Screed
- Sealant, adhesive, and filler
    - Bitumen coating
    - Bitumen adhesive, sealant, and filler
    - Bitumen grouting compound
    - Sealing tape and thermal bridge interrupter
    - Sealant
    - Liquid foil
- Sealing sheet, vapour barrier, foil
    - Waterproofing membrane
    - Vapour barriers and brake
    - Film protection material
- Wall element
    - Chipboard concrete wall element
    - Wall element made of lightweight concrete
    - Wall element made of cellular concrete
- Wall paint and covering
- Water
- Window and window component
    - Window (total)
    - Window frame
    - Glazing
    - Linear thermal bridge coefficient (PSI value)

In its current version, materials of the third-party data sources Baubook, Ökobaudat and ASHRAE have been linked to the BIMERR material categories. The developed mapping methodology is described within the next section.

2.5 BUILDING MATERIAL MAPPING

The developed building material mapping methodology enables users to efficiently plug-in additional building material data and map missing data points for the LCA/LCC and energy performance calculation.

After loading the renovation project and corresponding IFC file in RenoDSS, the completeness of the building material data (thermal properties, LCA/LCC properties, etc.) will be checked (see Figure 3).

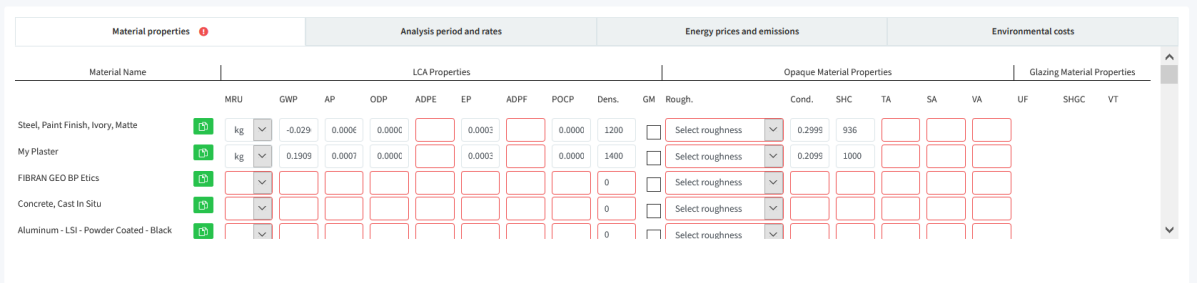

Figure 3: missing building material data check

If building material data is missing in the initial IFC file, RenoDSS supports the user at completing the data by the following building material mapping approach (initiated by clicking on the green button and shown in Figure 4 and 5):

- For each data point (MRU, GWP, AP, etc.) RenoDSS checks for existing mappings to similar building materials.
- For each data point without an existing mapping, RenoDSS provides the user a list of potential mapping candidates. Each building material which belongs to the same category and provides the missing data point will be shown as a potential mapping candidate. The candidates are sorted by the attribute which has been defined in the admin view for the specific category (see Section 2.6).
- When the user selects an alternative material, the value for which this material was selected is automatically updated with the value of the selected material. If the

materials reference units do not match, a unit conversion is done to the selected unit of reference. It is also possible to overwrite existing values with values from other materials or by manually providing the data. A checkbox is provided so the user can decide if they want to keep the original value or replace it with the new one.

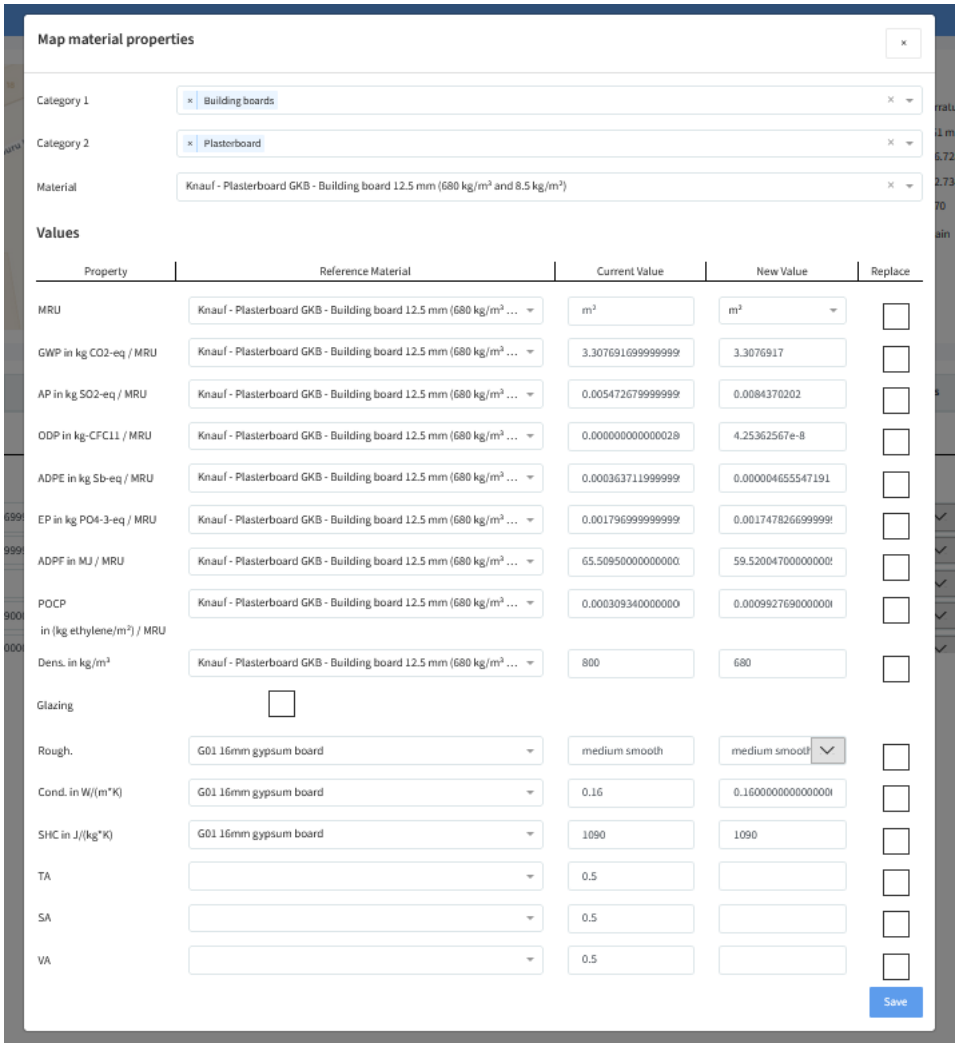

Figure 4: building material mapping modal

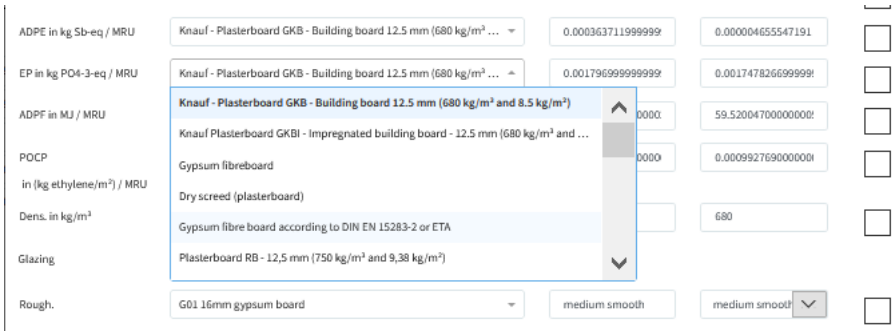

Figure 5: alternative material selection

Once the mapping is done all mappings are globally stored and thereby accessible to other users to minimize future mapping efforts (see Figure 6).

	project_uuid uuid	mapped_material character varying(255)	material character varying(255)	property text
1	cf69954f-e154-460a-bb43-dbbcb2ab7a59	5b5ee2e7-3113-4be3-b2cb-1444f3cbf5bd	299e80e2-8eff-4a03-a23d-a7100cd01a9c	ADPF
2	cf69954f-e154-460a-bb43-dbbcb2ab7a59	d583e97c-f8d0-46fc-baa3-a781e61aa28d	My Plaster	IFC MATERIAL
3	cf69954f-e154-460a-bb43-dbbcb2ab7a59	a952a2c5-f017-43fe-8d87-b06ad1ca9901	d583e97c-f8d0-46fc-baa3-a781e61aa28d	ADPE
4	cf69954f-e154-460a-bb43-dbbcb2ab7a59	a952a2c5-f017-43fe-8d87-b06ad1ca9901	d583e97c-f8d0-46fc-baa3-a781e61aa28d	ADPF
5	cf69954f-e154-460a-bb43-dbbcb2ab7a59	d546fec4-f297-4c48-8253-450245b24deb	d583e97c-f8d0-46fc-baa3-a781e61aa28d	ROUGHNESS
6	34b13100-1f45-4ed9-9546-776b74c51e52	77085396-a7ba-48bf-9ec8-f3cde3962896	Gypsum Wall Board	IFC MATERIAL
7	34b13100-1f45-4ed9-9546-776b74c51e52	d546fec4-f297-4c48-8253-450245b24deb	77085396-a7ba-48bf-9ec8-f3cde3962896	CONDUCTIVITY
8	34b13100-1f45-4ed9-9546-776b74c51e52	d546fec4-f297-4c48-8253-450245b24deb	77085396-a7ba-48bf-9ec8-f3cde3962896	SPECIFIC HEAT CAPACITY
9	34b13100-1f45-4ed9-9546-776b74c51e52	299e80e2-8eff-4a03-a23d-a7100cd01a9c	Concrete, Cast-in-Place gray	IFC MATERIAL
10	34b13100-1f45-4ed9-9546-776b74c51e52	5b5ee2e7-3113-4be3-b2cb-1444f3cbf5bd	299e80e2-8eff-4a03-a23d-a7100cd01a9c	ADPE
11	34b13100-1f45-4ed9-9546-776b74c51e52	5b5ee2e7-3113-4be3-b2cb-1444f3cbf5bd	299e80e2-8eff-4a03-a23d-a7100cd01a9c	ADPF

Figure 6: DB view of mapped materials

Figure 7 shows the completed building material data after the mapping.

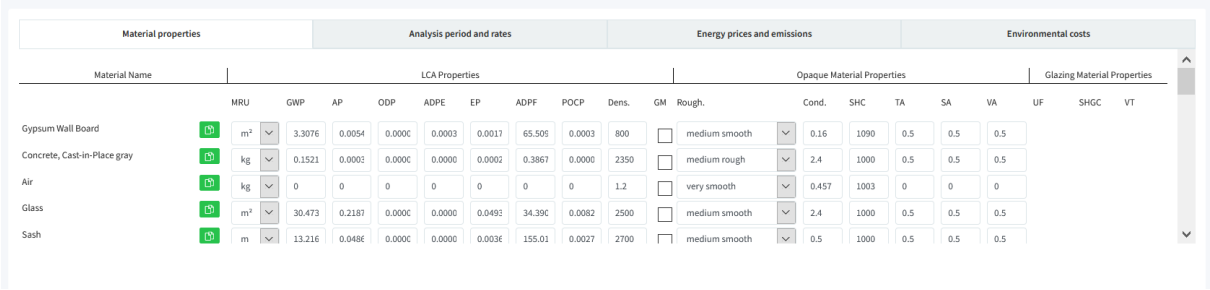

Figure 7: completed building material data

2.6 SORTING PROPERTIES FOR BUILDING MATERIAL CATEGORIES

For users associated with the admin role an interface to select a sorting property for each material category is provided. The sorting properties are used to order the list of similar materials so that more similar materials are shown first to the user. This helps the user to find a matching material more easily. Each category/subcategory can have its own sorting property:

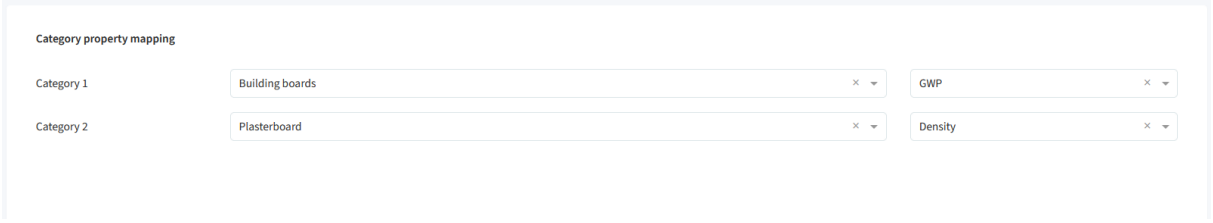

Figure 8: defining sorting properties for each material category

The values of the category property mapping are stored in database table *glb_category_property_map* (see Figure 9).

	id bigint	uuid uuid	category_id text	property text
1	1	8085dd10-7657-462e-ae38-790e1b922bf8	16128	GWP
2	2	a915dee9-590b-48f5-b35a-dccf0d7346f1	16129	GWP
3	3	e358322c-f220-45ac-b2f7-5a318cd4f29a	16130	GWP
4	4	381a91bb-2c60-4f78-a21b-ee833658bce4	16131	GWP
5	5	1dbbbdd1-ca6f-44b1-b03e-00819f412f77	16132	GWP
6	6	0d34d300-a12a-464f-8097-3d936aa5b3ef	16133	GWP
7	7	d6aff477-a380-4f5d-bf98-e577d2ffdb61	16134	GWP
8	8	3141c1a6-7cfa-4201-8a28-fa06de8c9996	20395	GWP

Figure 9: category property mapping

2.7 ADDING, EDITING AND REMOVING BUILDING MATERIAL DATA AND MAPPING DATA

For users associated with the admin role an interface is provided to show all building materials and their properties. The list can be filtered by categories and specific materials can be found using the search bar (see Figure 10).

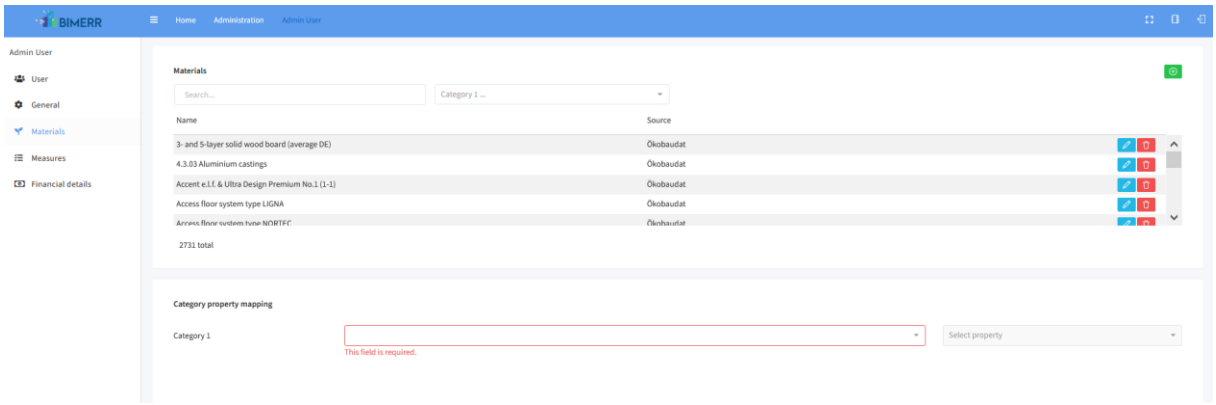

Figure 10: admin material view

The user can add new materials and edit or remove existing materials globally. The user interface for new materials and editing materials allows the user to either manually provide necessary values or use the mapping functionality to copy values from other existing materials (see Figure 11).

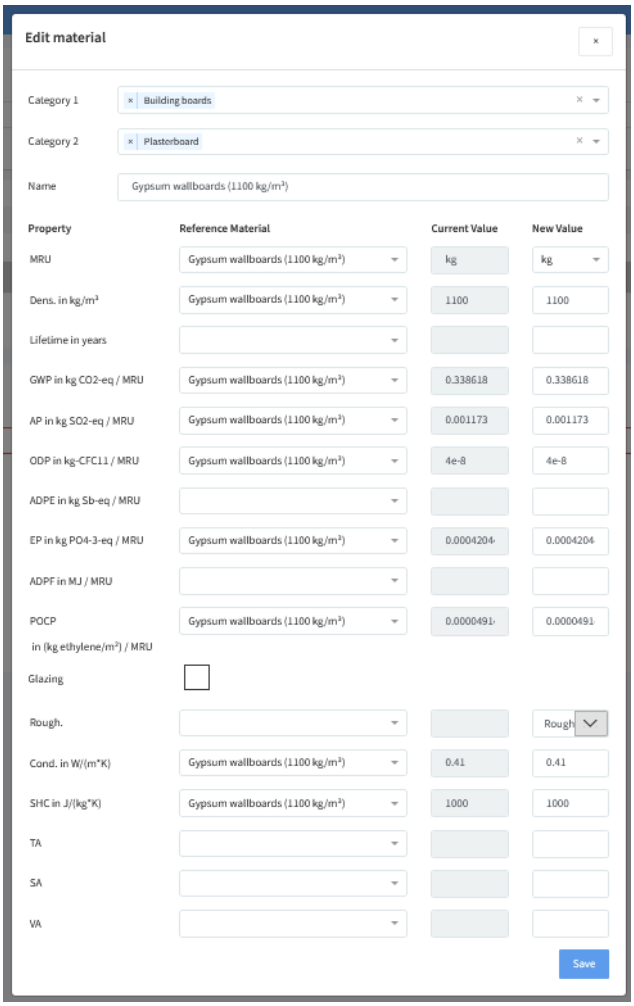

Figure 11: modal for adding / editing materials and mappings

2.8 TECHNOLOGY STACK AND IMPLEMENTATION TOOLS

The BIMERR Material and Component Database is based on state-of-the-art technologies and three layers:

- The Presentation Layer, containing the endpoint through which BIMERR applications can retrieve the data and the administration user interface which allows the user to set his/her data retrieval preferences. The REST interface is hosted by Apache Tomcat, the user interface is built upon Angular, Typescript, and NGRX Entity/Store.
- The Business Logic Layer which transforms and harmonizes the data according to the user's preferences is written in Java and executed by Apache Tomcat.

- The Data Layer that utilizes PostgreSQL to store the actual building material data.

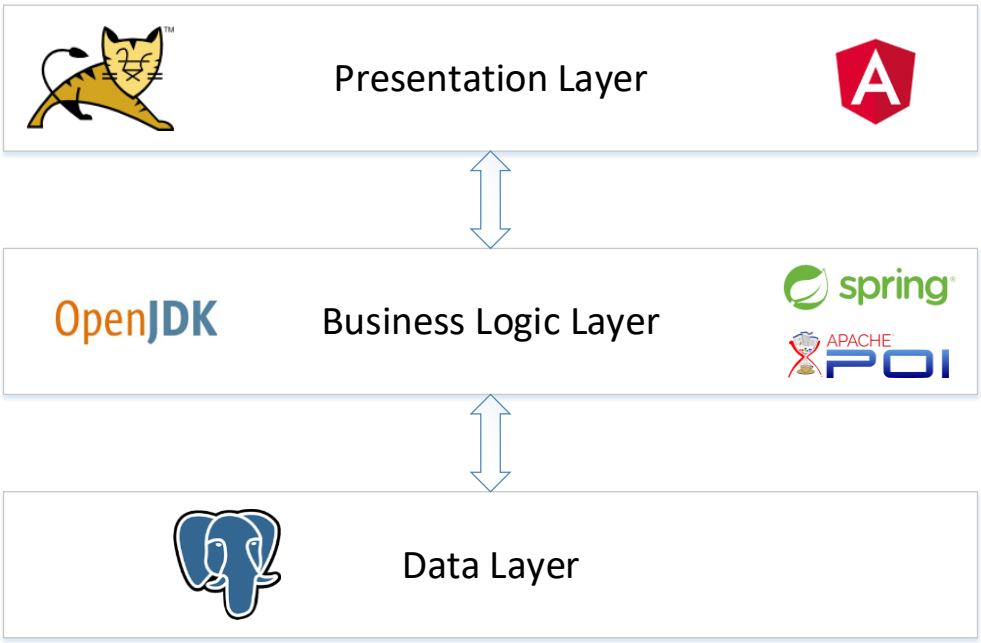

Figure 12: architecture of the BIMERR Material and Component Database

The BIMERR Material and Component Database utilizes the open-source technologies and libraries as defined in the following table.

Table 1: Technologies and libraries used in BIMERR Material and Component Database

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
Apache POI	4.1.2	Apache License 2.0 license
Hibernate	5.4.8	LGPL 2.1
PostgreSQL	9.5	PostgreSQL License (similar to BSD/MIT)

2.9 API Documentation

Please see D7.1 for a full documentation on the BIMERR Material and Component Database API.

2.10 Assumptions and Restrictions

The current release of the BIMERR Material and Component Database is based on the following assumptions/restrictions:

- Components (heating systems, PV systems, etc.) are limited to the absolute minimum which is necessary to run the demo use case and will be extended as planned in T8.1.
- Project-specific costs for material and labour must be provided by the user, as it was not possible to centrally obtain this data for all possible project configurations (location, project size, building type, etc.). However, the RenoDSS LCA/LCC module provides default cost values based on cost data of similar projects which are stored in RenoDSS.

2.11 Installation Instructions

The database is accessible via a web-based API, and therefore does not require installation or downloading of any component to use it.

2.12 Licensing

The material category schema is public. For the third-party material information (Baubook, ökobaudat, and ASHRAE) the licensing of the respective vendors applies. As parts of the BIMERR Material and Component Database are based on the Xylem business intelligence platform it is a closed source component.

3. END-TO-END USAGE WALKTHROUGH TO THE BIMERR MATERIAL AND COMPONENT DATABASE

In this section we present an end-to-end usage walkthrough of the BIMERR material and component database. As detailed information on the single steps is already provided in the previous sections, we focus in this section on overall workflow.

1. Adding and modifying global building material and component data

The admin user can add new or modify existing building materials and components by the views shown in Figure 13 and Figure 14. Changes made by the admin user are available to all RenoDSS users. Reference materials can be defined for each material property to fill up missing property values (see Figure 14).

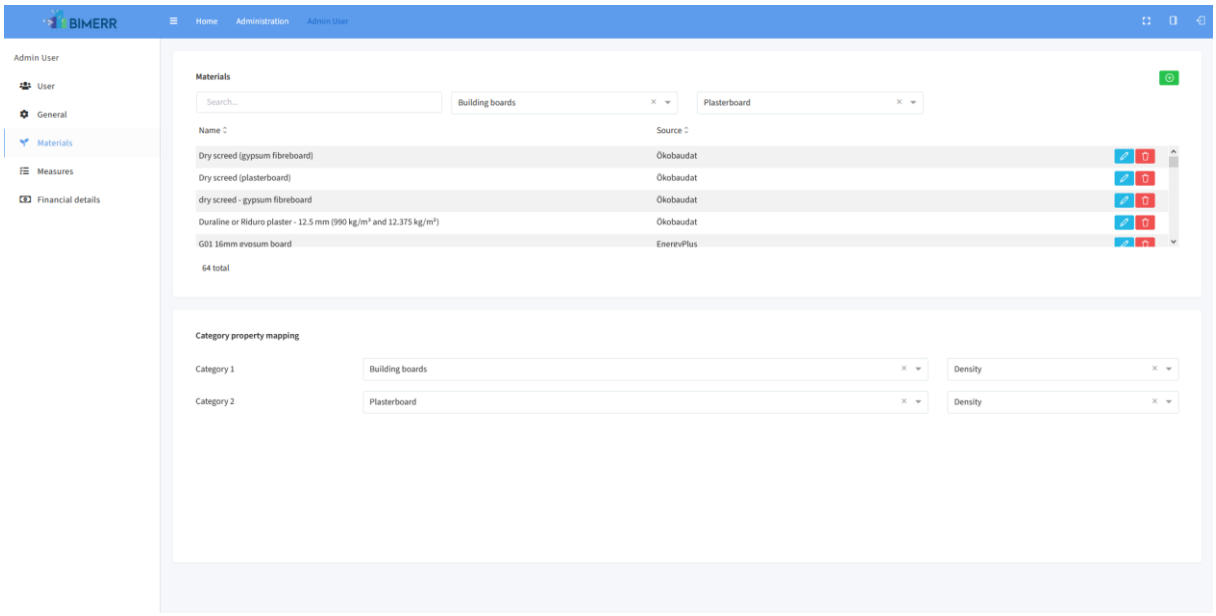

Figure 13: admin user: adding/modifying building materials and components - category property mappings

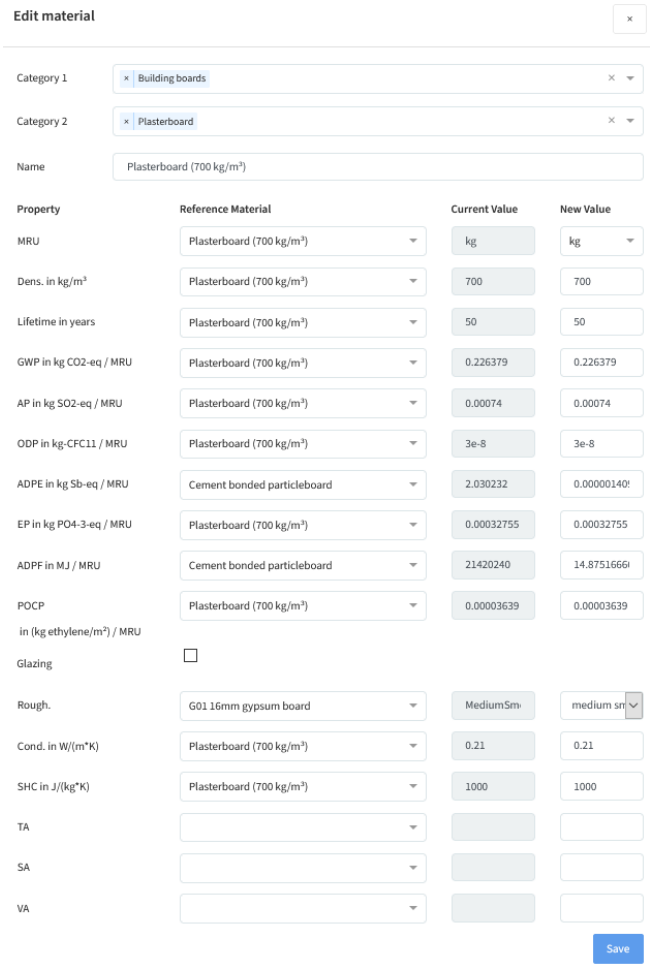

Figure 14: editing building material data

2. Loading and completing IFC-based building material and component data

Building material and component data defined in Step 1 is used to complement missing building material and component data after loading the building's IFC file. Whenever an IFC file is loaded, RenoDSS checks if all necessary data for conducting the LCA/LCC, energy performance, and urban planning calculations is available (see Figure 15). If the IFC file lacks required data, RenoDSS allows the user to obtain the missing data from the RenoDSS building material and component database (see Figure 16). By selecting alternative materials for missing material property data as shown in Figure 16, the user creates a mapping between the material and the alternative material. These mapping are stored globally and are available to all RenoDSS users.

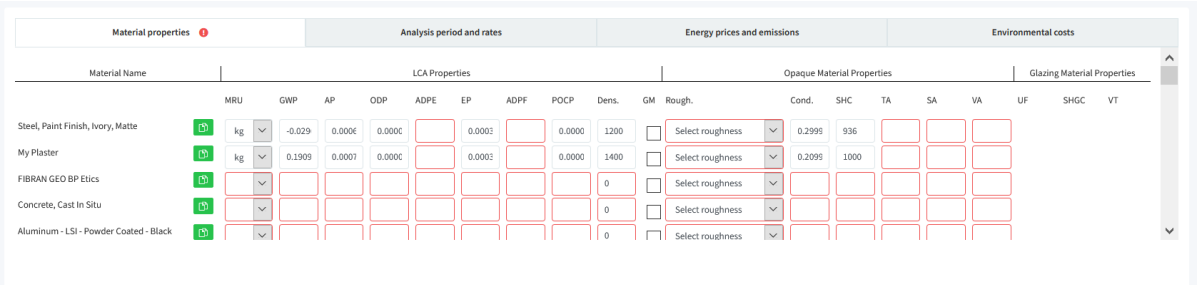

Figure 15: missing building material data check

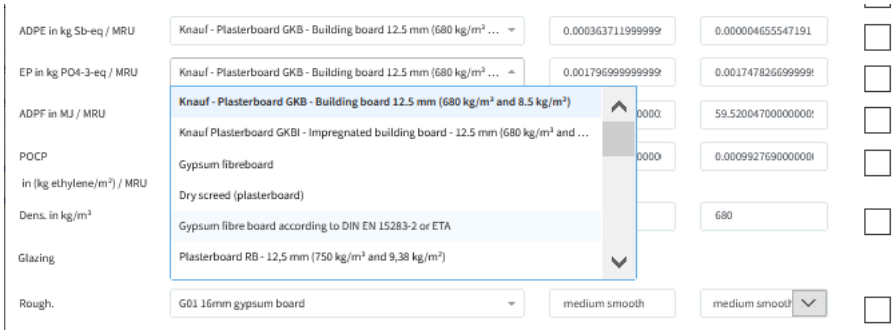

Figure 16: alternative material selection

3. Applying existing material mappings

Whenever a new IFC file is loaded, RenoDSS extracts relevant building material information from the IFC and checks for existing mappings if not all required material properties are present in the IFC file. Figure 17 shows a complete set of building material properties which was created by applying building material mappings.

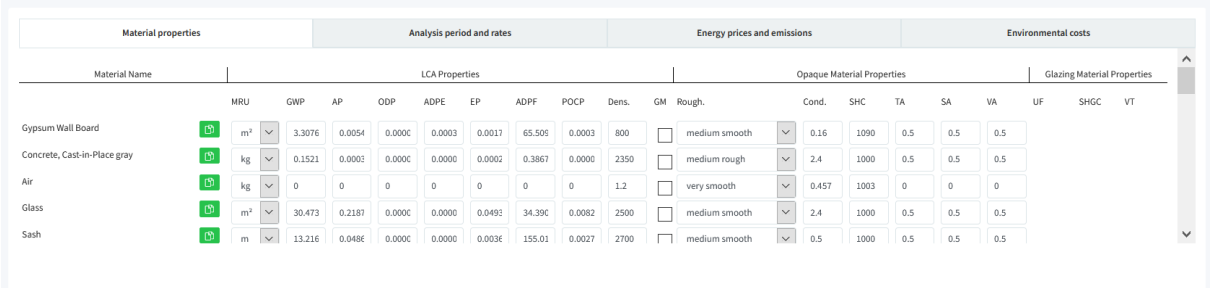

Figure 17: application of existing material mappings

4. CONCLUSIONS

The final BIMERR Material and Component Database provides

(i) BIMERR applications via an endpoint with technical, financial, and environmental data about 1.198 building materials originating from Baubook, Ökobaudat, and ASHRAE,

(ii) a building material mapping approach which can be used to semi-automatically map similar building materials across different data sources and thereby enables the user to select the data sources which are used to populate the required building material property values in the context of a specific renovation project,

(iii) an end user interface for managing existing and new building material data sources and building material categories, and

(iv) an end user interface for manipulating building material and material mapping data.

The BIMERR Material and Component Database can be accessed via REST endpoint by other applications and the following data can be retrieved from the endpoint: (i) timestamp of the latest database update, (ii) full list of materials without material details, (iii) full list of materials with material details, and (iv) material details of given material.

5. REFERENCES

Baubook: URL: www.baubook.info

D3.1 “Stakeholder requirements for the BIMERR system”

D3.6 “BIMERR system architecture final version”

D7.1 “Populated Material/ Component Databases 1”

D9.2 “Report and associated material on BIMERR stakeholder engagement & training activities”

DIN-EN-15804: URL: https://www.beuth.de/de/norm/din-en-15804/148775446

Ökobaudat: URL: www.oekobaudat.de