A BIM object library for buildings energy efficiency renovation

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Abstract
Building renovation is one of the current big challenges of the construction sector, which would improve the sustainability of existing structures, in terms of energy and emission savings and, as a consequence, would reduce the overall energy and CO_2 emissions accounting in the building sector. Within the EU-funded Research Project BIMSPEED (H2020-GA 820553), a BIM object database has been developed as a support for the renovation design. The database lists the components mostly used in renovation projects, enclosing a set of general and specific properties, which can be used in a BIM environment for running energy performance and sustainability assessments. The database has a web interface where the objects can be visualized and downloaded and can be enriched with external existing libraries and with new datasets coming from components manufacturers, after passing an internal data quality check.

Keywords: Renovation design, BIM, LCA, LCC, BIM object database

1 Introduction
Among all the industrial sectors, the construction one is considered to be highly resource-consuming. In particular, according to the Building Performance Institute of Europe, the building sector accounts for 40% of energy consumption and 36% of CO_2 emissions. Moreover, most of the European existing residential buildings have reached the age for renovation. While new buildings can be realized with high energy and emission-saving performances, the existing buildings are mostly characterized by very bad performances and, therefore, their renovation can contribute to the fulfillment of the sustainability goals in the construction sector. The EU-funded Research Project BIMSPEED (H2020-GA 820553) aims at providing all stakeholders in the housing renovation market with holistic solutions regarding: an affordable cloud-base BIM platform; a set of inter-operable BIM tools; validated and standardized procedures for implementing renovation solutions with guaranteed energy performance and inhabitants' comfort. Within the BIMSPEED Project, a BIM object database has been developed as a support for the renovation design. The database is made of building components that can be used for building renovation, each dataset being equipped by a set of general, energetic, environmental and economic parameters.
The database has several aims: firstly, it allows general construction building stakeholders to view and choose the more appropriate building renovation component, also with the help of

research filters; then, it allows to use the datasets for performing energy performance assessment and environmental and economic analyses in ad-hoc external tools.

2 Description of the BIMSPEED Database

The BIMSPEED database is composed of a number of materials and components used for deep renovation of buildings. Building renovation components are defined as the building elements that can provide a contribution to the reduction of the overall energy consumption and/or to an enhanced environmental and economic sustainability. The database collects a set of parameters, which can be divided into two packages: the "info package" and the "software package". In particular, the info package includes the general information, such as the component category, the typology, the application area, and others; whilst the "software package" includes more specific information, i.e. the data needed as support for energy performance assessment, Life-Cycle Assessment (LCA) and Life-Cycle Costing (LCC). Data collected for the energy performance assessment vary considering different components categories. All the components and the related parameters will be discussed in the following subsections.

2.1 Building renovation components

In order to define the BIMSPEED database, the renovation components need to be identified. To this aim, a grouping in made considering the building components that are applied on the envelope of the building and the ones related to the Heating, Ventilation and Air Conditioning system (HVAC). Indeed, in the first group, the components applied on the building envelope, i.e. external walls, roof, ground, and contributing to the energy efficiency, are included. These are: insulation materials and panels, facades, ventilated facades, windows, external doors. The HVAC system components can be installed inside or outside the building and contribute to the mechanical heating, cooling, and ventilation of the building. These are the components for water heating system; air/water conditioning system; small Variable Refrigerant Flow (VRF); multisplit; and ventilation. Moreover, a third renovation component group is added to take in consideration the Domestic Hot Water (DHW) systems components. Table 1 schematizes the listed components.

Table 1. List of components included in the BIMSPEED database

Group	Building Component - Category
Envelope	Material
	Panel/Roll
	Facade
	Ventilated facade
	Ventilated roof
	Window/Door
HVAC	Water Heating System
	Air/Water Conditioning System
	Small VRF
	Multisplit
	Ventilation
DHW	Domestic Hot Water

2.2 Info package

In the Info Package, general data are provided, which aim at the identification of the component and also at guiding the database user to choose the building component which better suits his/her renovation design.

In particular, info data can be grouped into five sub-packages, being: General Package; Dimension; Fire Package; Durability package; Energy Classification. In the General Package, the

following data are gathered: Group; Category; Type; Application area; Name; Description; Brand; Producer Web Site; Main Material; Source BIM Object.
The possible groups and categories are listed in Table 1, in the first and second column, respectively. Types are indeed depending on the component category; some of them are reported in Table 2 for an easier exposition.

Table 2. List of Types for all the building components categories

Category	Type
Material	Thermal insulation Acoustic insulation Thermo-acoustic insulation
Panel/Roll	Thermal insulation Acoustic insulation Thermo-acoustic insulation
Facade	Thermal insulation Thermo-acoustic insulation
Ventilated facade	Thermal insulation Thermo-acoustic insulation
Ventilated roof	Thermal insulation Thermo-acoustic insulation
Windows/Doors	Side-hung (1 door) Side-hung (2 doors) Side-hung (n doors) Sliding (1 door) Sliding (2 doors) Sliding (n doors) Top hung Tilt and turn Pivot vertical Pivot horizontal
Water Heating System	Gas boiler Electric boiler Biomass stove

The application areas are the sites where the component is applied, being the external wall, the internal wall, the floor, the roof, the ground and/or the ceiling. Then, the name, the description of the components, the producer and its website are collected. The main material of the component and, finally, the website where the BIM file can be downloaded are reported.
The second sub-package regards the dimensions. This info is particularly important for the components included in the envelope group, whilst is not collected for the HVAC and DHW systems, since they can be composed of more than one element. The fire package collects the information on the Euroclass - Fire, being A1, A2, B, C, D, E, F according to the EN 13501-1 and, also in this case, it is needed only for the components of the envelope group. The durability package collects the component's Reference Service Life (RSL), reported in years. RSL can be particularly important for helping the database user to identify his/her best choice. The last information of the general package regards the energy classification, which is collected only for the HVAC and the DHW systems components.

2.3 Energy performance package

The identification of the necessary data to be addressed to the building renovation components for running the energy performance assessment has been a quite hard exercise. Firstly, it was decided to collect all the necessary data considering the different categories, therefore the

energy performance package has been divided into the following sub-sections: Materials/Panels/Rolls; Windows; HVAC - Water Heating System; HVAC - Aerothermal System; HVAC - Small VRF/Multisplit; HVAC – Ventilation; DHW.
For an easier exposition, the energy parameters to be collected for each components categories, and their relative unit of measures; some of them are schematized in Table 3. It can be noticed that for the water heating system and the air/water conditioning system, the component can be used not only for heating/cooling, but also for the production of DHW, which can have or not a storage system. This means that relative additional data need to be collected.

Table 3. List of energy parameters for all the building components categories

Category	Energy Performance parameters
Material Panel/Roll Façade Ventilated façade Ventilated roof	Vapour resistance (μ) Conductivity of materials [W/(mK)] Thermal resistance of unit area of materials [(m^2K)/W] Thermal transmittance of unit area of materials [W/(m^2K)] Thickness [m] Density of materials [kg/m^3] Specific Heat of materials [J/(kgK)]
Windows/Doors	Heat transfer of transparent elements [W/(m^2K)] Air permeability of transparent elements [m^3/(hm^2)] Percentage of opaque elements [%/100] Heat transfer of opaque elements [W/(m^2K)] Solar absorptivity opaque elements [%/100] Transmittance of solar energy [-] Window Thermal transmittance (W/m^2K)
Water Heating System	Boiler type Nominal Power [kW] Fuel type Rated Efficiency at 75°C [%] Operating temperature [°C] Design delta temperature [°C] Terminal unit type

2.4 Sustainability package

The sustainability package collects the environmental and economic impacts of the building components considering the stages of their life-cycle. In particular, the life-cycle stages are related to the EN 15804, which classifies the building product lifetime into four main modules:

- Modules A1-A3 (Production stage), i.e. the extraction and production of the raw materials, the transport to the manufacturing site and the product manufacturing;
- Modules A4-A5 (Construction stage), i.e. the transport to the installation/construction site and the product installation;
- Modules B1-B7 (Use stage), i.e. all the operations that can happen during the product use, such as maintenance, replacement, repair;
- Modules C1-C4 (End-of-Life stage), i.e. all the operation related to the product End-of-Life, such as deconstruction, waste processing, disposal.

In the LCA package, the information related to the environmental impacts generated during the A1-A3 stage are considered, with reference to a fixed unit of measures, called “Functional Unit”.
In the LCC package, the information related to the economic impacts generated during the Production, Construction, Use stages are considered.

For the LCA and the LCC, the data included in the database are reported in Table 4. It can be noted that the LCA parameters are equal for all the categories, whilst the LCC parameters differ

for the envelope and HVAC/DHW categories, because an additional cost info is collected, i.e. the energy cost.

Table 4: List of LCA parameters for all the building components categories

Category	LCA parameters	LCC parameters
Material Panel/Roll Façade Ventilated façade Ventilated roof Windows/Doors	Functional Unit Global Warming (kg $CO_{2,eq}$) Acidification (kg $SO_{2,eq}$) Eutrophication (kg $PO_4^{---}{}_{eq}$) Ozone Layer Depletion (kg CFC-11 eq) Photochemical Oxidation (kg NMVOC) Abiotic Depletion, elements (kg Sb_{eq}) Abiotic Depletion, fossil fuels (MJ)	Functional Unit Price Construction/ Installation Costs Maintenance Costs in RSL
Water Heating System Air/Water Conditioning System Small VRF Multisplit Ventilation Domestic Hot Water		Functional Unit Price Construction/ Installation Costs Maintenance Costs in RSL Operational Energy Costs

3 Database Web Interface and functionalities

The database has been initially developed on an excel file and manually populated with around 200 datasets in order to identify critical issues for the collection and to validate the parameters previously identified. The datasets parameters have been collected by searching them on the producers technical datasheets and websites, and, when not available, by directly contacting the producers or by setting conventional values provided by literature (e.g. for the Reference Service Life and Costs parameters), or also by performing specific analyses (e.g. for the Environmental parameters).

Lately, in order to start the automation for the compilation, a website has been realized which allows the admin and users who have been given the access to visualize the datasets and to upload new ones. Figure 2 shows the dashboard of the online version of the database. In Figure 2 the web page for compiling a new element included in the "Panel/Roll" category is visualized considering the data uploading functionality (in the first page, data from info package can be added).

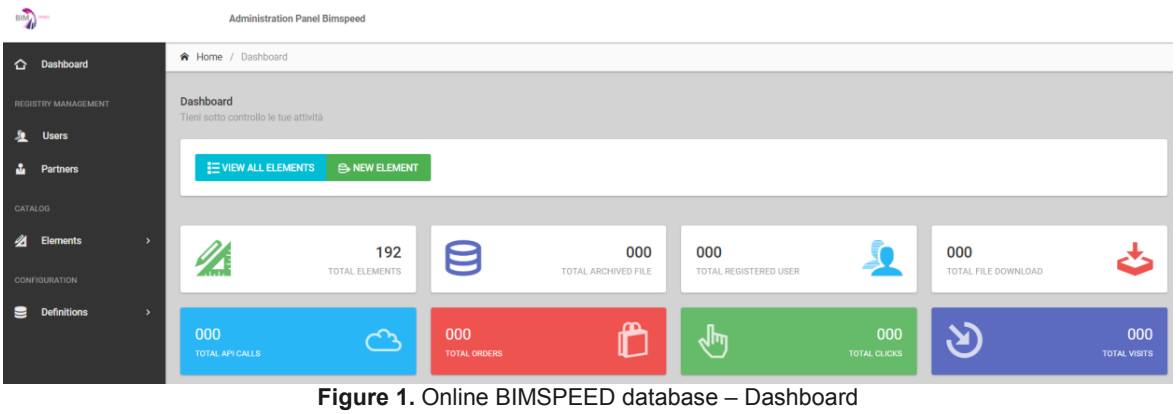

Figure 1. Online BIMSPEED database – Dashboard

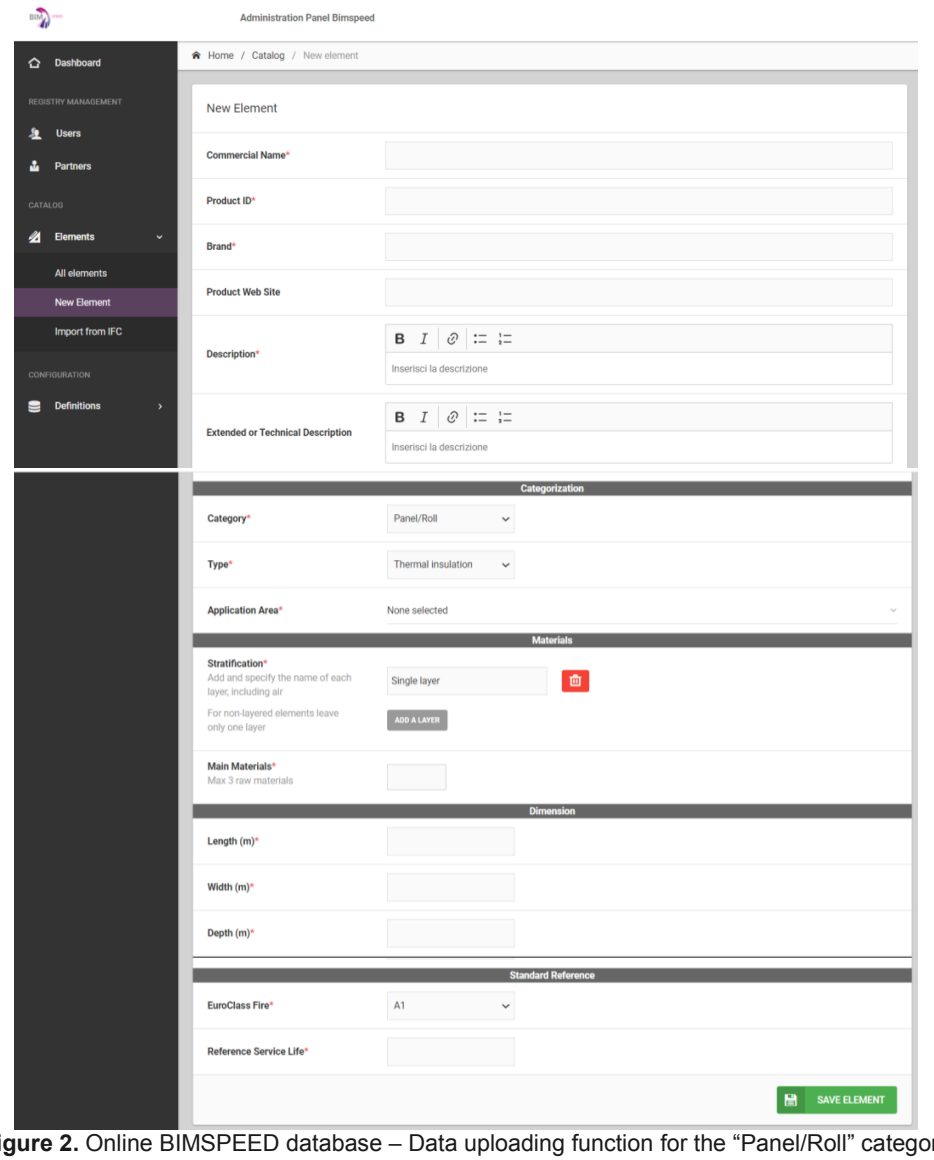

Figure 2. Online BIMSPEED database – Data uploading function for the "Panel/Roll" category

The online format of the database communicates with a web portal, having a graphical interface. The web portal is helpful for generic users who want to search and visualize renovation BIM objects, by also using search filters that can suit their necessities. Users can also register to the portal, allowing them not only to search and view BIM objects, but also to download them and, possibly, to upload new ones. The possibility to upload new renovation objects is strictly related to a data quality check. Indeed, in order to be included in the BIMSPEED library, the datasets need to include the required parameters, which must be consistent with the other library objects in terms of parameter typologies and related unit of measures.

4 Communication with existing BIM object libraries and external services

The boundaries of the described database can be enlarged in order to add new inputs and outputs.

Several BIM object libraries are available online. Some of the most important ones are BIMObject® , MEP Content, BIM Store, National BIM Library, and others. Such existing libraries collect a big amount of data and BIM files. Nevertheless, the data are not homogeneous and can be used for different aims, according to the parameters included in the BIM file. In order to take advantage of these existing libraries and to add some of them in the BIMSPEED library, it is necessary to make them consistent with the database structure, i.e. to include the parameters required by it, in terms of typology and unit of measure. To this aim, a data quality check is

performed, which finally states if the object can be or not included in the library and, if not, which data need to be added/modified. In case few data are needed, a manual data inclusion is made.
As anticipated, the final aim of the database is to help performing energy assessments and sustainability analyses. Therefore, a BIMSPEED library API is developed, which can be read by external software (Figure 3). In particular, the database has been developed in order to be easily read by the energy performance tools using "Energy plus" as energy simulation program. Also the environmental and economic data can be used as support for sustainability analyses to be run on existing sustainability tools.
The BIMSPEED library can have multiple uses. One of them is to make it available as BIM software plug-ins. In this way, the library can be easily explored directly inside BIM software, such as Revit or others.

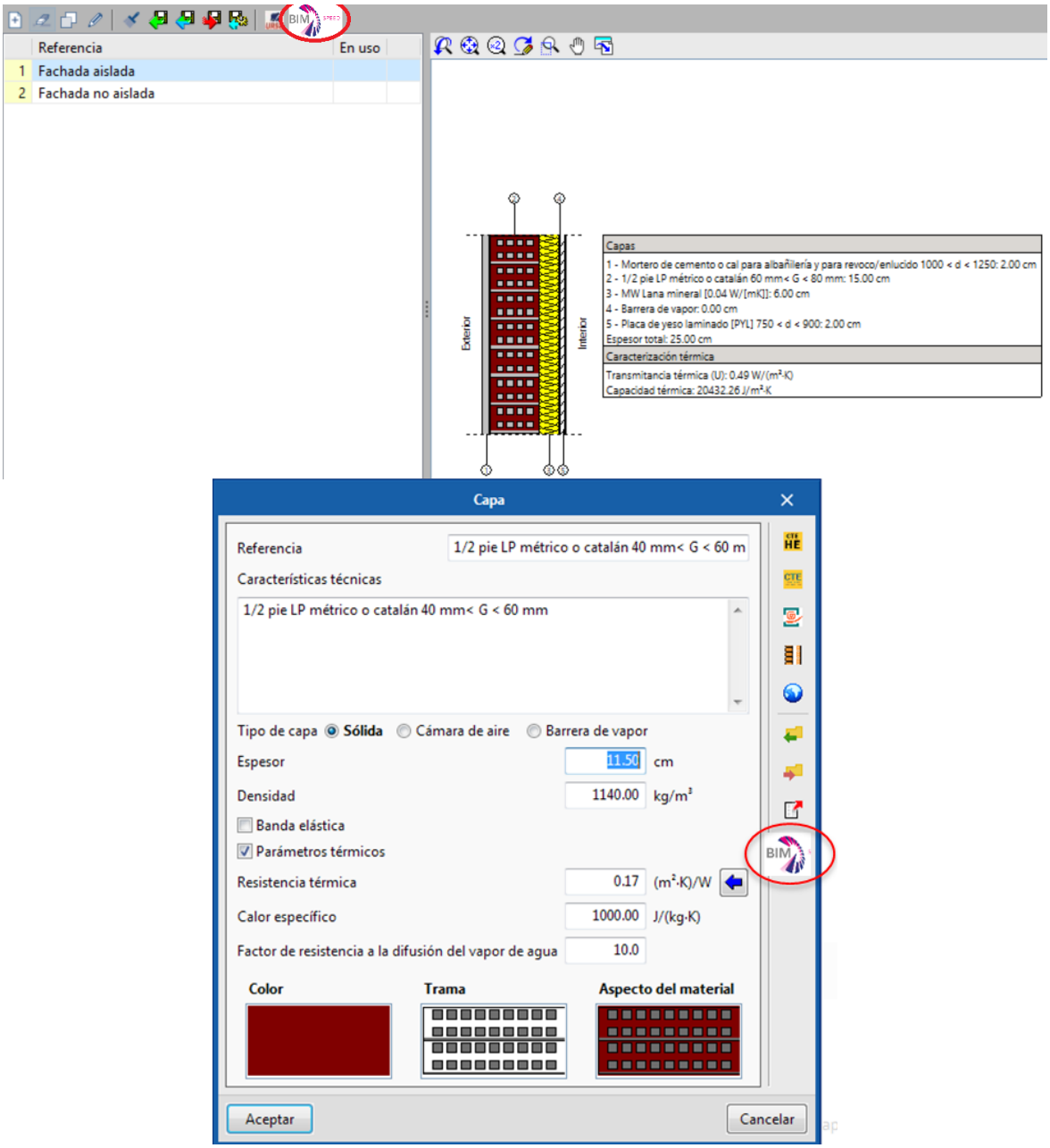

Figure 3. Examples of the introduction of the BIMSPEED library in existing tools, such as Cypetherm

Within the BIMSPEED Project, several inter-operative tools have been developed. CSTB realized the "ifc LOD filter" application, which allows to replace the existing element included in a BIM-based building project, with other elements, by changing the inner parameters (Figure 4). The BIMSPEED library can be used to enlarge the library already included in the application, together with providing the overall file additional energy information.

Figure 4. Lod filter tool developed by CSTB – example of element substitution by assigning a new product

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BIMObject® Library, available at https://www.bimobject.com

MEP Content Library, available at https://www.mepcontent.com/

BIM Store Library, available at https://www.bimstore.co/search

NBS National BIM Library, available at https://www.nationalbimlibrary.com