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BIM-BEM support tools for early stages of zero-energy building design

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Abstract. Due to the Energy Performance of Building Directive 2010/31/UE (EPBD) recast, new and existing buildings have the aim to achieve the Zero Energy Buildings (ZEBs) requirements, in order to reduce the carbon emission and the energy building demand. Therefore, the building process cost is increasing, related to the applications of performant construction and efficiencies energy systems. In literature, several studies highlight the importance of innovative approaches in order to reduce the cost of the ZEB targets achievement, during the early stage design process. In this framework, Building Information Modeling (BIM) is a useful process that integrated building design since the first design stage, providing high-performance energy solutions and obtaining a single model reducing time and cost during the building design. In fact, in Italy, the regulatory obligations are progressively defined: with the Ministerial Decree 560 of 1 December 2017 (Baratono Decree), the time scale with which the obligation to use BIM will come into force has been established. The obligation started from 1 January 2019 for public tenders for an amount equal to or greater than 100 million euros, then there will be a gradual entry up to 2025 for public works contracts worth less than one million. The research proposes a new workflow that allows to performing energy analysis through the BIM and Building Energy Modeling (BEM) optimization interoperability, allowing to support the zero-energy building during the early stage design.

1. Introduction

Nowadays, the development and application of Building Information Modeling (BIM) in the architecture, engineering, and construction (AEC) sectors are still growing. In literature, BIM definition is well described by Eastman: “a modelling technology and associated set of processes to produce, communicate, and analyse building models” [1]. Furthermore, BIM process has been considered as an efficient tool to be used during the preliminary building design phase since it allows to easily and better manage and evaluate architectural, energy, environmental, and life-cycle assessment of the project [3-5]. According to the Energy Performance of Building Directive 2010/31/UE (EPBD) [6] recast, new and existing buildings have the aim to achieve the Nearly Zero Energy Buildings (nZEBs) and Zero Energy Buildings (ZEBs) requirements, in order to reduce the emission and the heating and cooling energy demand of the entire buildings sector. The term NZEB is used to define a building whose energy consumption is almost zero or, in other words, a building that produces an amount of energy equal to the building demand on one year of its operation [7,8]. In order to comply with the nZEB and ZEB requirements, the use of well-performing materials and efficient technical systems become fundamental, with the consequence of increasing the entire building process costs. Therefore, many researches underline the necessity to identify new methodologies to optimize the ZEB development during the design process, to reduce delays and costs increase in the construction phase. In this context, the BIM technology could have a wide application allowing to manage the design process in an integrated way by the creation of a unique model for a different types of analysis, which includes all the information in



a unique database. One of the problems emerged in this framework is the capability of data exchange among different simulation software to create a unique model containing all the types of information (i.e. geometry, energy and environmental performance, architectural features). Many studies have been developed for optimizing for example the interoperability process between the BIM and BEM (Building Energy Modeling) tools due to the wide type of energy engines available on the market which create problems related to data transfer [9]. In this framework, the research aims to implement and test a new workflow that allows to optimize the BIM-BEM interoperability for energy performance assessment of buildings. It would allow to facilitate the achievement of ZEB requirements and to reduce costs and time in the building design stage. The model format that guarantees data exchange between BIM and BEM tools is the IFC scheme. IDA Indoor Climate and Energy (IDA ICE) software was chosen for the energy and environmental performance analysis of the building since it supports the IFC format and allows to reduce data loss in the model import phase. Finally, through the IDA ICE Simplebim plug.in, the IFC file has been added with the energy simulation results, providing a final BIM file which contains all the geometrical, architectural and energy information.

2. Method

This study aims to implement BIM-BEM interoperability process, in order to facilitate the achievement of ZEB targets and to reduce time and cost during the early stage building design, providing a full detailed unique model which contains energy analysis results. IDA ICE, developed by EQUA Simulation AB (Equa Simulations), is chosen as the energy software due to the easy import of IFC BIM models inside the energy tool. Indeed, today several architectural and BIM applications use IFC data format for data exchange, but few energy software, such as IDA ICE, can import IFC file directly, without middleware tools. Among the IFC (Industry Information Classes) data format, it is a file schema that transfers important information about the type, properties, and building composition. Heating, cooling and domestic hot water simulations are performed for the presented case study, a single dwelling located in Rome. IDA ICE provides an important add-on called "Simplebim", able to check IFC information, during the export and import process and it allows to merge the IFC model with a different kind of information. In particular, it allows to clean up the model to data that are not useful for energy simulation (e.g. furniture, landscape and so on) and to merge energy analysis results back to the IFC model in order to reduce data loss and to visualize all the information inside a unique file. Finally, in order to analyse the energy simulations output, another model of the presented case study is created directly inside the IDA ICE software. The comparison between energy results provided by the IFC import and the IDA ICE modelling highlight the methodology validity and usefulness. Therefore, thanks to the use of BIM process, it is possible to get a single integrated file, containing energy and architectural information (also structural, mechanical, electrical and plumbing) useful for the achievement of zero-energy building targets and for the costs and time saving of early-stage ZEB design. Methodology workflow is summarized below and shown in Figure 1:

- I. The architectural model: the first step is to create the architectural model in the BIM software Revit, including all its geometric, spatial and thermal characteristics. Once the 3D model is completed, all the attention is devoted to the exporting information set for the IFC file.
- II. Importing the IFC into IDA-ICE: The second step includes the IFC control and clean up with the Simplebim add-on and consequently import the file into IDA-ICE energy simulation tool.
- III. The Energy Simulation: In the third step the energy simulation is set up and described in detail.

IV. Merge IDA-ICE results within the IFC file. In the last step, Simplebim IDA-ICE add-on merges energy simulation results to the IFC file for having a single completed file.

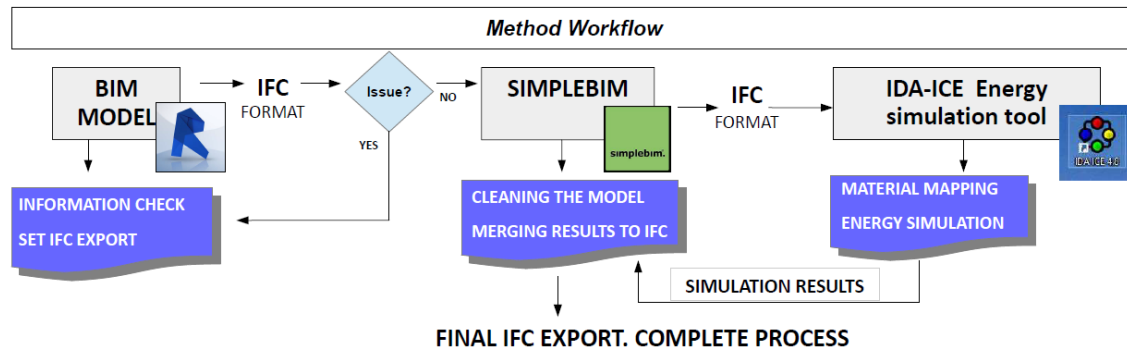


Figure 1. Methodology workflow

3. The case study

The case study is a single dwelling of two floors sites near Rome (lat. 41.94, long. 12.44). The first floor of 110 m² is composed by an entrance hall, a toilet room, and a living room, the second floor is about 60 m² and is composed by two bedrooms and one bathroom (table 1). Information about the building and characteristics of the material construction are summarized respectively in table 1 and table 2.

Table 1. Building data

Model floors area	Model volume	Model envelope area	Window/Envelope	Average U-value
169.3 m ²	625.6 m ³	449.9 m ²	9.2 %	0.6647 W/(m ² K)

Table 2: Characteristics of opaque materials construction

Partition	Total Thickness (m)	Materials	Thickness (m)	Thermal conductivity (W/mK)
External walls	0.30	Plaster	0.015	0.9
		Solid brick	0.12	0.72
		PUR (polyurethane)	0.03	0.022
		Solid brick	0.12	0.72
		Plaster	0.015	0.9
Internal walls	0.18	Plaster	0.015	0.9
		Solid brick	0.15	0.72
		Plaster	0.015	0.9
		Ceramic tiles	0.02	1
		Screed	0.025	0.47
Floor	0.28	Concrete reinforced	0.22	2.3
		Plaster	0.015	0.9
		Ceramic tiles	0.02	1
		Screed	0.025	0.47
		Sand	0.02	0.33
Ground floor	0.40	EPS	0.09	0.036
		Concrete reinforced	0.25	2.3
		Floor coating	0.02	0.18
		Screed	0.025	0.47
		Sand	0.02	0.33
Roof	0.40	Waterproof sleeve	0.05	0.044
		EPS	0.09	0.036
		Concrete reinforced	0.25	2.3
		Plaster	0.02	0.9

Table 3: Characteristics of glass materials

Window	Dimensions	Trasmittance (W/m ² K)
3 pane glazing, clear, 4-12-4-12-4	1.5 m x 2 m	1.9
3 pane glazing, clear, 4-12-4-12-4	0.8 m x 2 m	1.9

I. First step: The architectural model

The first step of the procedure requested the 3D modelling of the case study. Autodesk Revit was used for the purpose. This is just one of the several building information modelling tools available on the market. In order to facilitate the creation of energy data, it is essential to comply with precise modelling rules in order to simplify the transmission process to the simulation software. The following are the indications that have been found essential through this study for correct modelling:

- All the objects must be constrained to the correct level in which the geometry is located (wall, windows, slabs, doors).
- The spaces/thermal zones are mandatory, without them IDA-ICE can't accept the IFC file. The space name is the only necessary request for linking thermal properties and making the energy simulation possible. Before exporting, area and volume computation have to be activated.
- A wall must be horizontal, with his original profile (not edited) and contained in only one building storey, this means may be only one level high. A wall must be Vertical, with constant thickness, and defined with the correct thermal properties, this facilitates construction element merging in IDA-ICE. The wall layers are also considered constant all over the wall.
- All the objects of the architectural model different from the construction elements are ignored.
- Complex shapes (in particular curtain walls) must be simplified before importing into IDA-ICE. For example, curved shapes are usually split into few linear walls.
- The measuring system is also important. IDA-ICE uses the International System so the best choice would be to use the same, to avoid the conversion process.
- IDA-ICE considers the ground level at zero elevation of the building's local coordinate system.
- A building storey footprint should not contain holes.
- Before exporting the IFC file, "Space boundaries 2nd level" and "Export Revit property sets" must be chosen.

II. Second Step: Importing the IFC into IDA-ICE

Once exported from Revit, the next step is to import it into Simplebim. As specified earlier, this step is important in order to check what is correctly exported. This allowed finding some modelling errors in the BIM model that can be recovered before making a new export. Once the IFC file is loaded into IDA-ICE, it is proceeded to map all the construction elements imported with the materials of the energy simulation software.

III. Third Step: The Energy Simulation

In this study, heating and cooling needs are simulated for each room, through the "Ideal heater and cooler" devices. Those ideal room units only have a maximum capacity parameter, that allows users to experiment with the limited heating/cooling capacity [10]. Setpoint temperatures are imposed for the winter season and the summer season, respectively 21 °C and 26°C. Regarding thermal gains, for this preliminary energy demand, are not considered. Finally, for domestic hot water demand, input such as number of the person and litre per capita are complied, following the UNI/TS 11300 [11]. Energy analysis are carried out for the entire year.

IV. Fourth Step: Merge IDA-ICE results within IFC file

The last step of the research was to use the ability of SimpleBIM of merging IDA-ICE simulation results to the original model and exporting them to a new IFC File. This is a unique and interesting feature because there are few tools available on the market that allow combining an IFC information file with the energy simulation results.

4. Results and discussion

Simulations have been carried out for the entire year (2017). The figure below shows the energy need results: it possible to notice that the heating demand (34 kWh/m²y) is higher in January and December, the cooling demand (40 kWh/m²y) has its peak in July. Regarding domestic hot water (15 kWh/m²y), it slightly increases during the winter season.

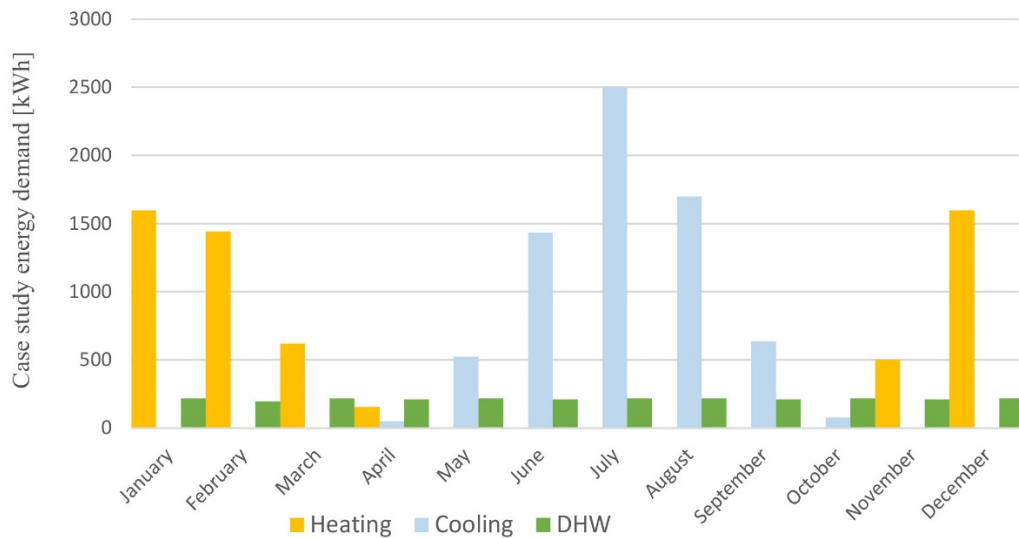


Figure 2. IDA-ICE energy results from IFC import.

In order to validate those results, the case study was modelled directly inside the IDA-ICE software, without importing the IFC. Same energy simulation conditions are set up. The percentage differences between energy results providing by the IFC import model and IDA-ICE model is about 5%, as shown in figure 3.

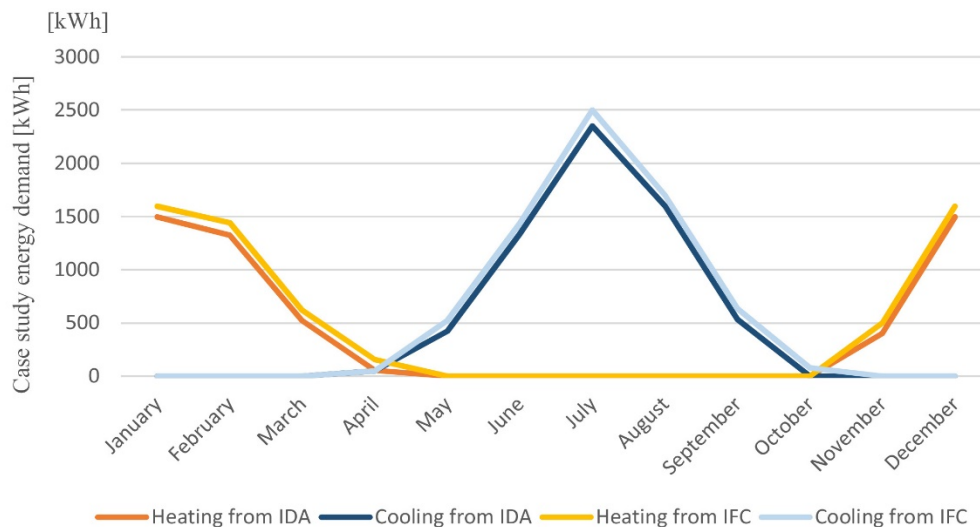


Figure 3. Comparison between energy results from IFC import and IDA-ICE model

5. Conclusions

Two aspects emerged as priorities for engineers and architects in the development of zero-energy buildings: the detailed energy assessment and the reduction of time and construction costs. In this framework, BIM could be a potential instrument for reducing costs and time during the building-design stage, providing a unique integrated file which contains architectural and energy information. Due to the well-known difficulties in the BIM-BEM interoperability, the goal of this work is to develop and verify a new methodology for overcoming the gap between BIM and energy models and facilitating the use of BIM within the ZEB construction process. The results confirm the applicability of the proposed methodological approach. The complete IFC file obtained in the last step of this workflow contains both the complete architectural data and building energy performance information, useful for the verification

and application of ZEB targets. On the other hand, the use of a unique model file limits the possibility of error caused by the development of different simulations models during the design process and, consequently, reduces costs and time. Nevertheless, despite the general interest, the use of BIM in Italy is still poorly widespread. It is considered an innovative solution but its straightforward application is still remote, apart from regulatory obligations. Future researches aim to improve this methodology, reducing data transfer errors, and to investigate the use of other energy software coupled with BIM, in order to simplify and facilitate the ZEB achievement.

Acknowledgements

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