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Building Renovation with BIM: 3. BIM to Building Energy model (BEM)

Bulding Renovation with BIM

A Practical Guide

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3. BIM to Building Energy model (BEM)

3.1 Introduction

3.1.1 What is BEM and what are it' s uses

In simple terms, a building energy model is a representation of the actual building, in terms of physical properties like building geometry, location, weather conditions, orientation along with occupant related data compiled in occupant schedules, energy use of equipment due to occupancy prevalence and building systems data is created by processes of mathematical modeling. BEM has been increasingly important in definition of high-performance buildings by assessing and improving building energy consumption, occupant comfort and efficient design of building systems.

An existing building which needs to be renovated, can in most cases, acquire data about utility from monthly bills about occupancy and model all components and end uses comprising the entire building. Such data and schedules about existing occupancy patterns are also difficult to compile even during operational phase of the building due to stochastic nature of building occupants. Furthermore, actual weather data instead of typical weather data is also collected for calibration. Having such data compiled, it is possible to calibrate the existing BEM to more accurately represent existing conditions. This calibrated model provides a better baseline for evaluation of renovation scenarios.

Development of a BEM aids in making comparisons of design strategies for a more efficient building renovation design. In addition to the use of BEM in design phase for renovation. It can be used to analyze heating and cooling loads for system design, lighting levels as well as compare energy assessment of materials provided by the manufacturers and services provided by sub-contractors. In addition to this, material documentation during the construction phase is also facilitated by BEM, for checking of compliance for energy efficiency related certification or for material passports. BEMs can also be used to improve building performance based on the operation phase by monitoring performance of HVAC and fresh air systems.

A BEM serves as the model that is assessed by certifying councils on building efficiency. Increasingly popular are LEED Certification and U.S Green Building Council to list a few, which certifies a building's compliance to existing regulations but also improved performance when compared to a baseline. The reference baseline for LEED Certification is ASHRAE 90.1. BEM aids in improving the performance of the buildings but also as an end goal, is the subject of test among various other factors for such certification councils as well.

3.1.2 Need for a BIM to BEM process

A BEM can be manually created firstly by independently modelling of the building geometry from 2D drawings which is followed by manually entering all energy analysis dependent parameters and materials followed by schedules of occupancy and operational parameters followed by data related to HVAC and other building energy dependent systems data. (Reeves, Olbina and Issa, 2015) This process leads to misinterpretations of drawings, inconsistencies, simplifying the models and not being able to capture the complexity of the model. In addition to these drawbacks, the time and effort required to create a BEM model using traditional process is large. The next section explains how using BIM as input could enhance the creation of BEM [**heffernan2017bim**].

Having a single source of information is proven to be beneficial to generate data driven information for generation of BEM. Contrary to the traditional process, a BIM based energy model allows a single source of information for all analysis related to energy utilization. The advantage of having a single source of truth is accompanied with several other benefits like enhancing or changing the central model (BIM) is translated to the energy model as well. Such translation of changes are beneficial for a design made through the design phase of renovation to construction, operation and end of life of the building. Design through several alternatives for analysis can also be enabled within the central source of information, while the energy simulation engine simulates these several scenarios from the BIM model or by using the BIM source as the guide for material and system description to carry out the analysis.

However, several comparative studies that divided and analysed data transfer in geometry, space type, zones, loads, materials and HVAC have been carried out and the results were concluded that there is information loss in the exchange of information from BIM models to BEMs and lack of a standard.

3.2 Information and Process

Some BIM pre-requisites in order to ensure the proper translation to BEM were identified as:

- proper orientation of the building with respect to the real North;
- proper classification of the building element functions (internal, external, in contact with ground);
- proper union of the building elements;
- all internal locals of the building must belong to a given space. Not empty areas should be left unmapped;
- no internal locals of the building can belong simultaneously to 2 spaces (spaces should not overlap);
- external shadowing buildings are modelled as mass blocks (exported as IfcBuildingElement-Proxy);
- for locals with different internal heights, auxiliary floor surfaces should be used;
- dealing with residential building, each individual dwelling should be considered as a single zone with no further partitions (C et al., 2021)

In addition to the above, certain aspects that needs to be given attention for the efficient translation of BIM to BEM are summarized in the following sub-sections.

3.2.1 Building locations

BIM models, at present do not contain information about the surrounding physical features as well as weather data of the location in which the building is situated. This is an essential aspect of BEM creation as weather data is a driver of internal thermal comfort in buildings. Current practices include addition of the weather data file prior to building energy simulations. Ideally, an existing BIM model which needs to be analyzed for renovation scenarios already contains the building location, however existence of the location and weather data used for energy simulations are to be

verified (C et al., 2021).

3.2.2 Building geometry

Creation and classification of the model into spaces and zones is a vital process for analysis of energy models. Incorrect definition of spaces occurs often when the 2D surfaces are aligned across 3D architectural building components. Clashes of spaces also occur when the various trades of building models are not well defined and segregated. Surface errors can also take place when there are redundant or ill-defined spaces or zones within the model. Translation of the BIM model geometry for BEM is one of the critical translational inaccuracies encountered in a BIM-BEM process. Model checking for translation process of BIM to BEM could possible identify such clashes and redundant spaces which could lead to an early stage correction of such modelling errors.

3.2.3 Building elemnents

BIM contains data of building elements which are required for the construction/renovation phase of the building. Contrary to this, a BEM required only thermal, geometric and material specific data required for analysis. Certain data regarding hardware of windows, for instance are not relevant for a BEM. The level of detail of information required for a BEM is different from a BIM. Early checking of such information is necessary to ensure a well defined translation from BIM to BEM. Another relevant aspect for BEM is to ensure the naming of all elements are effectively followed and that these are well translated from BIM to BEM. Most often, it is necessary to manually edit/enter some element names following the convention, within the energy simulation platform, for instance EnergyPlus.

3.2.4 Thermal zones

Definition of thermal zones is a critical aspect of energy models, and involves a lot of knowledge about building physics and energy use to define these zones. Such zones are often defined within a BIM model, however, they are not decided in great detail as in the case of a BEM. Often, this process is carried out within energy modeling tools, due to the level of detail needed to be considered while assigning zones. The creation of such thermal zones needs internal thermostat set point conditions, internal humidity and temperature conditions, occupancy related space usage and internal loads and geometry of the building which includes core spaces and adjacent spaces defined based on façade systems.

3.2.5 HVAC systems, plant, and equipment

System specifications are also an essential aspect of energy modelling and definition of such information in BIM when transferred accurately to BEM allows the incorporation of information needed for energy simulation. The data contained within BIM models must be coherent with the level of detail of systems and plant information required for energy simulation. If this requirement is not met, such data is entered manually within the energy modelling tool.

3.2.6 Schedules

Schedules within an energy model describe the usage of the building which is relevant for building an energy model. Existing data about occupancy and related operational parameters are collected from utility bills or sensors to make data driven occupancy models for energy simulations. Renovation projects thus, have access to historic data that can aid in occupancy modelling as well as bridge the performance gap that is often encountered due to inefficient modelling of occupancy related schedules.

Taking this into account the process involved in the translation of BIM to BEM has been

Figure 3.1: BIM2BEM process flow diagram

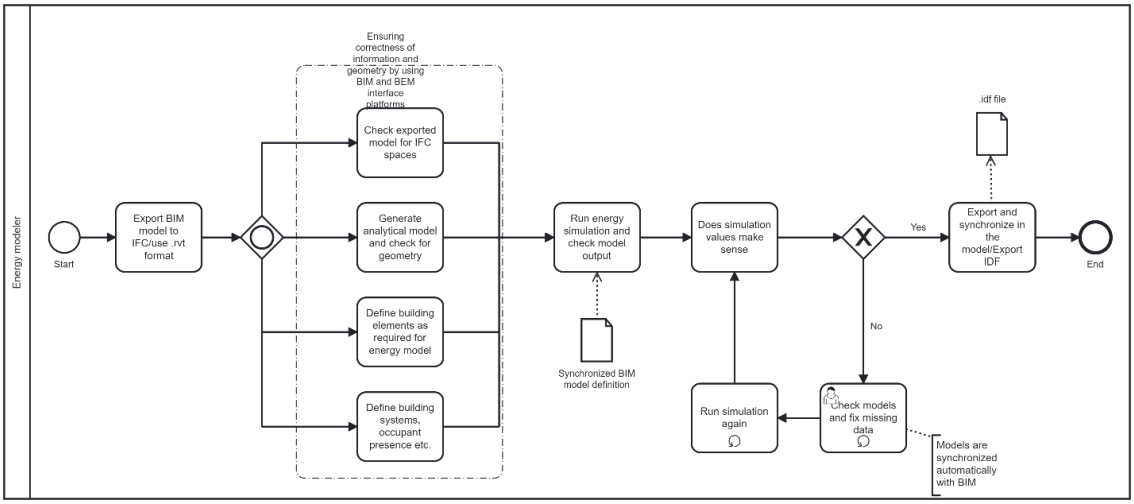


Figure 3.2: Tools for energy modeling

Energy simulation GUI only	Energy simulation engine	Independent energy simulation engine with graphical interface
OpenStudio *DesignBuilder* *Hevacomp* *Simergy* *BEopt*	⟷ EnergyPlus	Ecotect TRNSYS IDA ICE ApacheSim (used in IES VE) EDSL Tas Modelica language (can be used with graphical interfaces such as Dymola)
GBS eQuest RIUSKA	⟷ DOE2	

summarized as shown in 3.1.

3.3 BIM Tools with BEM capability

Several tools are available on the market to assess energy performance of a building. EnergyPlus is a widely adopted building energy simulation platform which has been developed on the strengths of DOE-2 and BLAST. The integrated simulation capabilities as well as user centric advancements like in the case of HVAC modelling, EnergyPlus allows performance-based equipment models. EnergyPlus provides options for selection of systems and equipment options.

Two data formats namely GBXML and IFC has been identified and implemented for interoperability. IFC, developed by buildingSMART provides specification of OpenBIM throughout the lifecycle of the building, thereby enabling collaborative design.

Some tools available in the market that allow the translation of BIM based information for energy models creation and analysis include OpenStudio, Virtual Environment, Insight 360 and many more. A tool used in the BIMSpeed Project was the Cypetherm Suite which is a collection of several tools that allows the sequential definition of BEM related information populated in the BIM model for the generation of the energy model.

The implementation of the BIM-BEM workflow with the aid of the Cypetherm Suite for sequential translation of the BIM model to BEM. This workflow was developed and tested within the BIM-Speed project on demonstration sites within the project. The process of implementation of

the Cypetherm Suite for creation of energy models is shown in **??**.

The OpenBIM workflow facilitates the generation of analytical models which can be checked for the geometric relationship. The OpenBIM Analytical model tool assesses and redefines the geometry of the spaces to facilitate the next processes of energy model creation while improving the accuracy of geometry translation. The Open BIM Construction System tool allows definition of the of systems and materials as required for the creation of the energy model. The final completion of BEM includes input of data including HVAC, operating schedules, set point temperature, internal gains etc. Upon input of all data relevant for energy models are completed, the generated model is checked for missing and wrong data which is carried out manually. However, any changes made are synchronized automatically.

3.4 Project Demonstration

The overall process was implemented on the Frigento democase. Frigento democase is a residential building called "Palazzo Testa Cipriano" located in the historical center of Frigento (Italy) in a densely urbanized context.

The BIM model of the building have been developed with Revit software and is available in the BIM-SPEED platform. At first, to integrate the Frigento BIM into the Open BIM workflow using the IFC standard, the plug-in Open BIM-Revit has been used to extract information from the BIM model and map data to readable file for CYPETHERM Suite tools.

The process of analyzing certain tools and procedures was carried out within the BIM-SPEED project in Deliverable 3.1"Analysis of BIM-to-BEM critical parameters and recommendation to solve the current bottlenecks". The "CYPETHERM procedure" is one such process and has been implemented on the BIMSpeed project. This section provides a practical BIM-to-BEM workflow, to create BEM models starting from BIM models and using a suite of tools to bridge the gap between the BIM models and the BEM models. This process has been recognized to incorporate the complete BIM-BEM process, optimizing the interoperability between BIM and BEM tool, which in turn has advantages of time savings as well as reduction in data loss while transferring data from the BIM model to the energy simulation platform.

The BIM-BEM process by Cypetherm has been implemented at the BIMSpeed project for several models for creation of energy models and simulation of renovation scenarios and the following advances for the drawbacks stated earlier have been identified:

- Extraction of information from the BIM model by this procedure has been facilitated by either the IFC Builder or using the plugin "Complementary Open BIM for Revit" which has a standardized process to export BIM models to IFC format.
- The analysis of IFC model through a GUI shows correct import of geometry, however some areas and volumes still require manual adjustment. Certain automation, for instance, automatic introduction of "Rooms" have also been identified. Materials thermal properties and stratigraphies, internal conditions related to occupancy, lighting and equipment and HVAC data and operation schedules still need to be entered manually.
- In general, this identified process enables accurate transfer of geometry and a semi-automatic synchronization between models, however a manual check of other energy analysis related parameters and manually entering certain element related data in the building energy simulation platform.

Using the Open BIM Construction System tool, the BIM-Speed Frigento project project has been selected together with the architectural and the analytical models of the building in order to characterize the building elements under the thermal point of view.

Once selecting the BIM-Speed Frigento project together with the all the models previously defined and synchronised on the BIMServer.center, the BEM model has been completed with the CYPETHERM Eplus tool. Concerning the weather data, the .epw weather file of the location has been linked to the BEM directly in Cypetherm Eplus, while concerning the HVAC system,

Figure 3.3: Tools for energy modeling

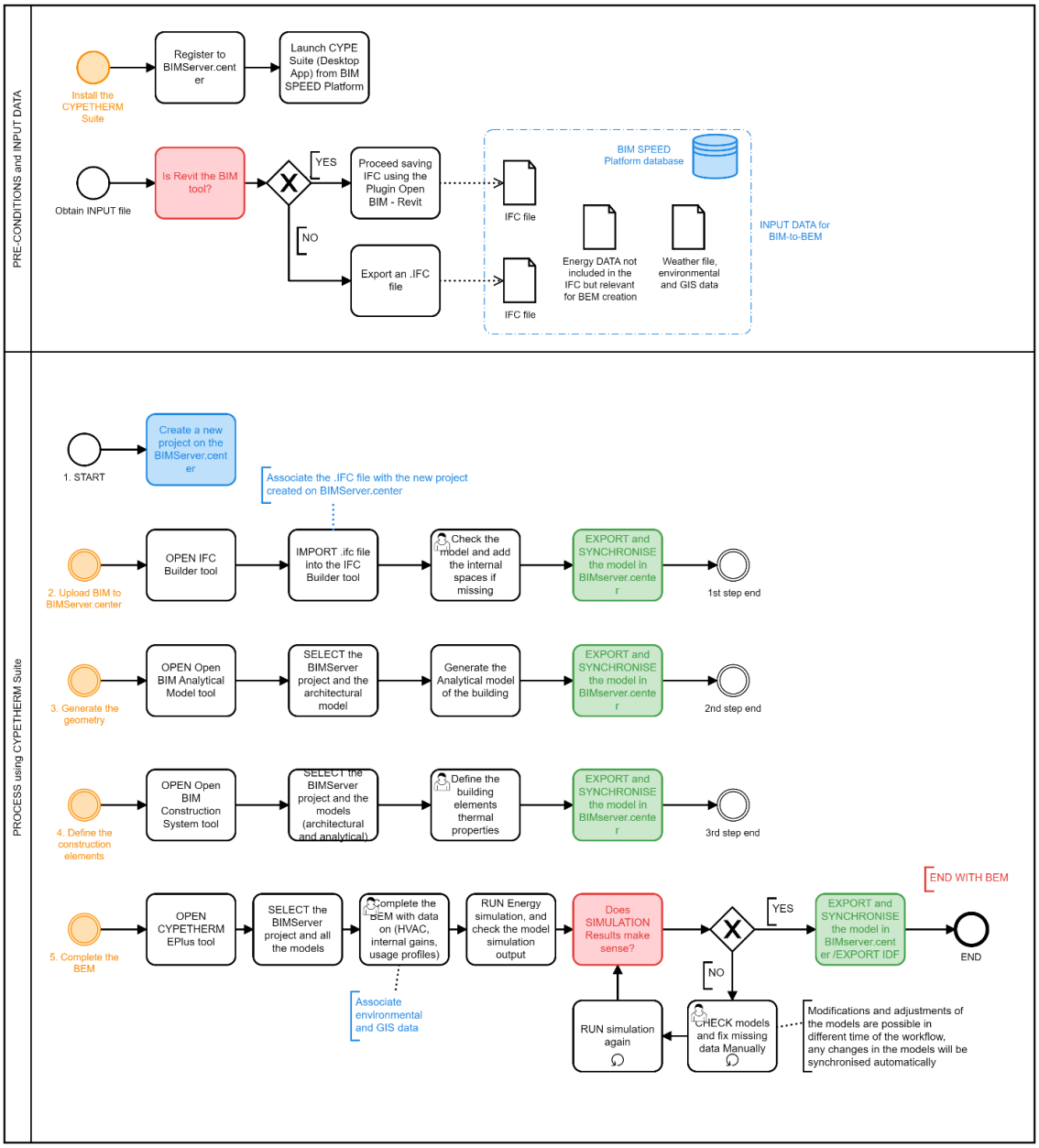
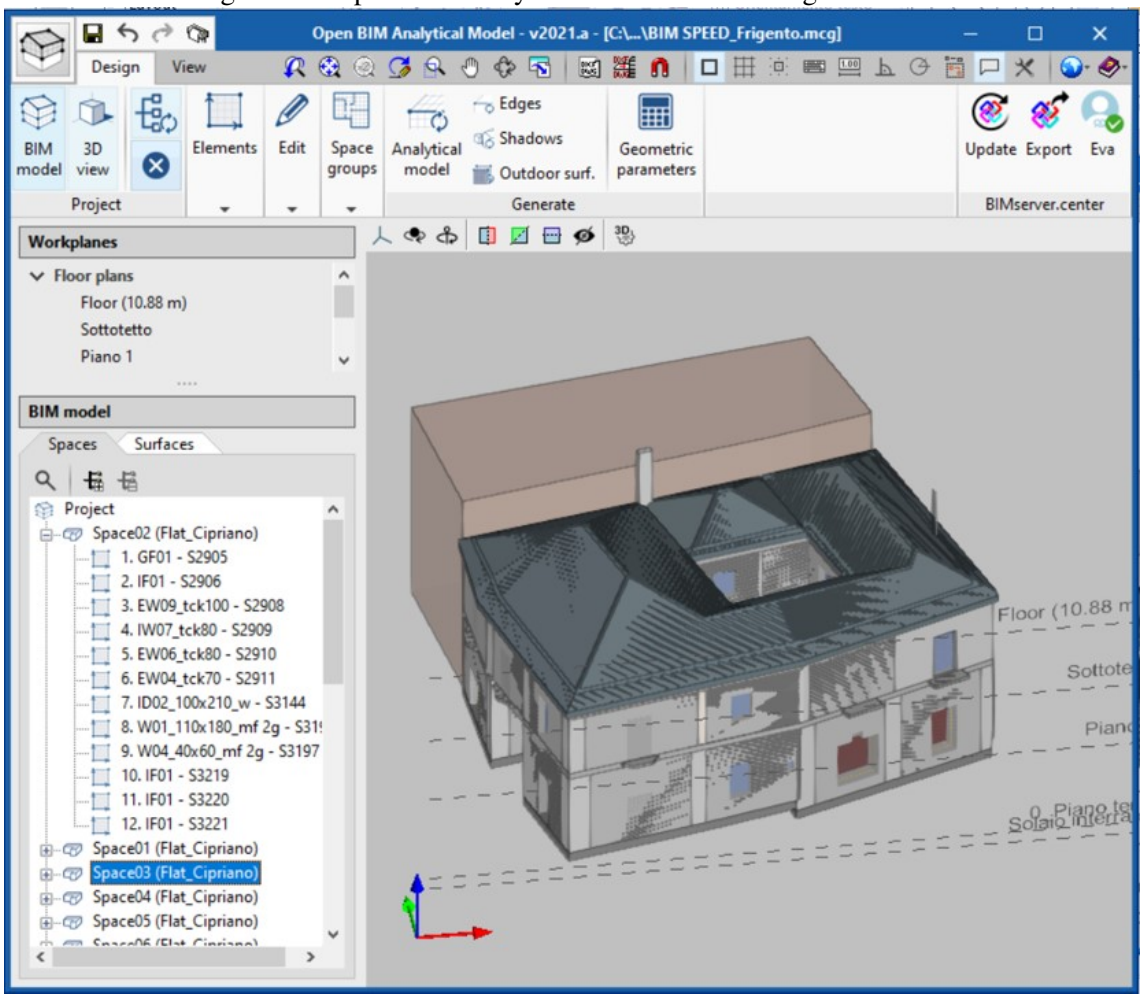


Figure 3.4: Open BIM analytics - creation of the Frigento model



2 separated heating systems (one for each apartment) with condensing boilers used both for the heating and the domestic hot water production have been modelled

3.5 Benefits of BIM2BEM

In addition to the general benefits of using BIM as the central information model for all analysis, that has been explained earlier within this chapter, a more focused analysis of benefits, using a BIM model as input for BEM and translation of the BIM to BEM process, by the Cypetherm procedure have been quantitatively and qualitatively realized as (Stage and Speed, 2022):

1. Reducing time for the BEM creation Automated translation of certain model data like geometry and other energy analysis necessary data has contributed to reduction in time for the whole process. As can be seen from the table below, geometry creation from both 2D and 3D models could be avoided due to the presence of BIM as the central source of information for the analysis. Transfer of available data from the BIM model to BEM model significantly reduces the need for collecting and input of data necessary for energy analysis into the energy simulation platform. Certain other inputs like material thermal specifications, HVAC system data and occupancy and operational parameter schedules need to be entered manually which remains the same as traditional processes. The results show a time reduction of about 44%, which is accounted largely to automated geometry and related other data required for energy analysis directly from the BIM model.
2. Retrieving geometry and other data directly from the already available BIM model, avoiding direct measurement and the construction of a 3D model from the beginning. The Open BIM Analytical Model solves the problem of lack of geometric accuracy and heterogeneity of definition of IFC files generated by different major BIM tools (Revit, ArchiCad, Allplan, etc). From any IFC containing the geometric definition of spaces, this application is able to recalculate its geometry and redefine all the edges and vertices of all the enclosures of the model received as input, so that it is ready to be calculated by subsequent thermal analysis tools.
3. The models are synchronized, a change within the IFC will then be read also in the final BEM The automation process enabled with a standard interoperable file format like IFC enables models to be synchronized thereby also reducing coordination complications. This has been identified as an advantage of using BIM to translate changes within all relevant analysis and stages of models throughout the building life cycle to integrate processes and information for efficient project delivery.