

# BIM and interoperability for energy simulations

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## Abstract

Energy efficiency issues are being integrated into Building Information Modeling (BIM) quickly by the InnovANCE Italian research project which provides the creation of the first Italian open-source construction "unified database", shared by all stakeholders: public and private clients, construction companies, professionals and manufacturers.

The aim of this research is to define a methodology by which to obtain data flows and information exchanges, with as small as possible data losses, from architectural software (as Revit Architecture) and energy analysis software, mainly those based on transient-state.

The transient-state tool analyzed for this study was the EnergyPlus simulation engine, which represents the state of the art tool in building energy simulation.

As the process of exchanging data from Revit to EnergyPlus is not direct, "Space Boundary Tool" (SBT) middle-ware was used as an "interoperable bridge" with good results passing through the Industry Foundation Classes (IFC) format, analysing problems and possible solutions. Up to now, SBT is used for three different purposes:

- (i) To apply needed geometric transformations in order to transform an architectural model into a two-dimensional surfaces model;
- (ii) To assign thermal boundary conditions to model surfaces and adding materials thermal properties;
- (iii) To get an .idf file that can be processed by EnergyPlus simulation engine.

The correct data exchange obtained makes the energy optimization process easier, mostly if applied in preliminary design phases (when energy analysis can be more effective in driving to the "zero energy building" goal), by avoiding building a new energy model for each architectural design variation.

## 1. Introduction

Energy efficiency issues need to be integrated in the building design process, mostly in the preliminary phase, to reach the zero energy goals. A way to make this operation easier is to provide a unique design base on which both architectural and energy experts can share their analysis and modification proposals. Providing a shared design base is one of the BIM aims. To actually ensure high-energy performances, transient-state simulation engines, like EnergyPlus (Crawley et al., 2001), should be used, but the complexity and particularity of models and data requested by these engines often make it hard to directly match with a BIM model.

The InnovANCE Italian research project was focused also on these items. It provided a web-based unified construction database shared by all stakeholders: public and private clients, construction companies, professionals and manufacturers. Some of the provided features of this web database, built together with SAP - Systems, Applications and Products in data processing, allow designers to download and upload information on materials, components, building spaces and projects, and their corresponding BIM objects with all needed properties already applied.

Therefore, starting from this data collector system, a workflow was developed in this study to build BIM models and perform transient state energy simulations on them during the design phase. The information transferring process between different tools belongs to the so-called interoperability issue, which was investigated in this study, by using the

“Industry Foundation Classes” (IFC) standard.

The BIM software used to perform these analyses was Revit Architecture, on which the “Add-In Innovance” was developed together with One Team software house to link the BIM model together with the InnoVANCE web database. EnergyPlus was the simulation engine on which energy evaluations were run.

## 2. Description of the experimental procedure of the InnoVANCE web database

In order to test the interoperability process, a simplified model was built, according to the BESTEST ASHRAE 140 reference. Therefore, the testing model was a single parallelepiped formed cell whose internal dimensions were 6.00 m x 8.00 m and 2.70 m height. Its longest side was oriented parallel to the East-West direction. On the south-facing façade two transparent components were considered, centered on the same, of dimensions 3.00 x 2.00 m.

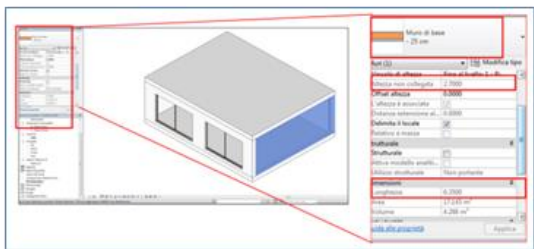


Fig. 1 – BIM model view of the test cell.

On the InnoVANCE web database the layers of the wall are looked up in the database of "element in opera" and, if they already exist, will be used in the "BOM creation"-Bill Of Material creation- of the parent material. In the case in which there is a layer that does not satisfy the requirements as requested, it will be necessary to create a new layer with the desired characteristics. This procedure can be done in two distinct ways: creating from scratch a new code which will be assigned to each of the seven characteristics - Function, Typology, Geometry, Heat resistance, Physic-chemical properties and Thickness - or by creating a copy of an existing code (which automatically assigns a new code to

the new copy layer) and then modifying one or more existing characteristics. This procedure guarantees an excellent applicability on the part of experts.

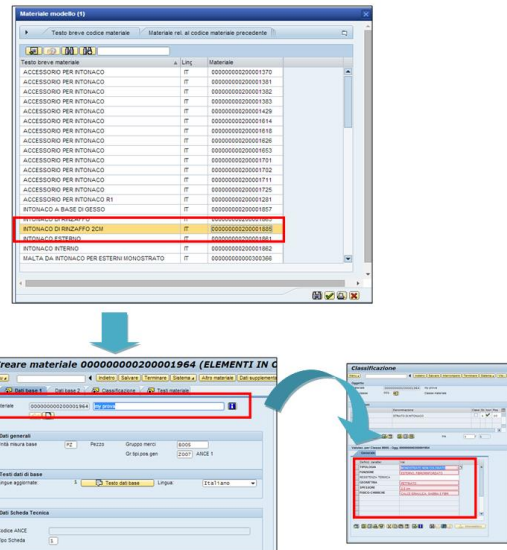


Fig. 2 – Possibility to rename the material and change each feature keeping other data.

## 3. Coding association in a parametric environment: description of the procedures

The association of a code in a parametric environment is necessary to identify each object in a unique way in the web database. This was done in Revit by using the InnoVANCE Add-In, which generates a two-way connection with the SAP programming code. In order to associate the BIM object, this has to be created before the object. Subsequently, in the Add-In box of InnoVANCE, clicking on ASSOCIATES, the "update objects – InnoVANCE materials research" dialog box is opened in which, under the heading "ANCE CODE" the code corresponding to the parent material to be associated to BIM object is inserted. In the "propriety of type" it is possible to find the characteristics assigned in the encoder for code generation. In the enclosed propriety under the heading "Other" the following fields are present: Thickness, Thermal transmittance, Physic-chemical properties, Function, geometry, Type, Ance code, extended text Ance material, Ance material.

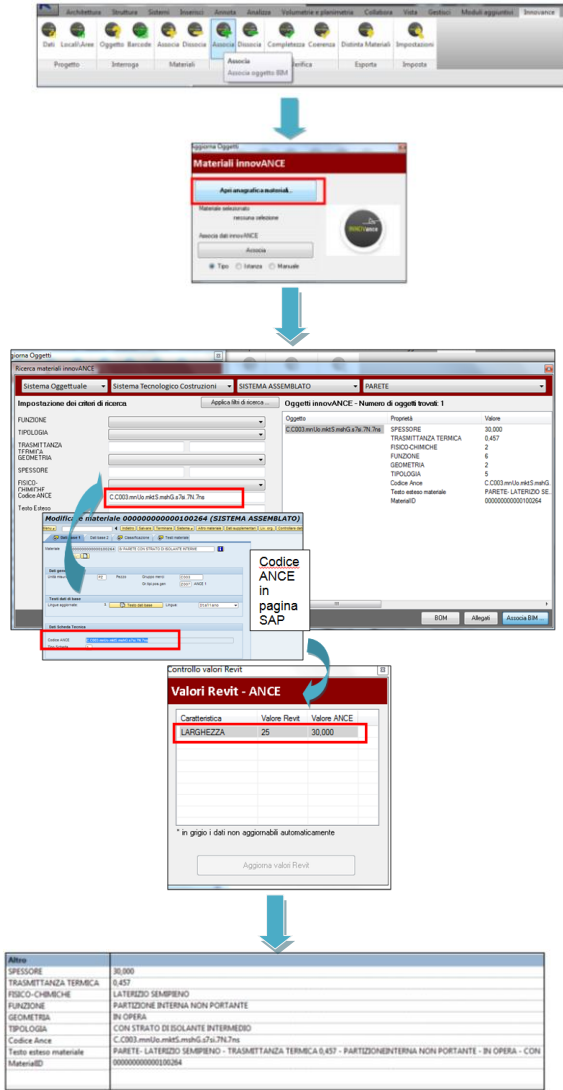


Fig. 3 – Association of a code to BIM object and visualization of characteristics in a parametric environment.

#### 4. Information's transfer checking from a BIM model to the .ifc file format by Revit

Once the code association of BIM objects to the Revit model was complete, the exportation in .ifc format was performed. Among the options that can be set in the procedure to generate .ifc files, users can also map BIM objects with the corresponding IFC classes, to ensure a conversion that corresponds to the standard of the format. In particular, some text files are already available with these pre-compiled maps and they can be loaded in order to automate this operation.

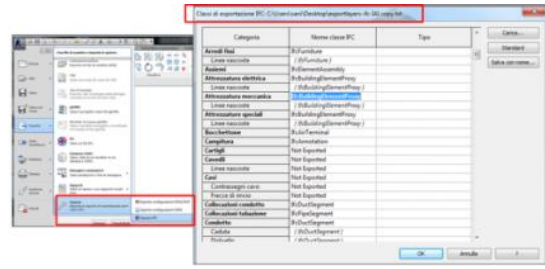


Fig. 4 – Mapping of BIM objects with the corresponding class according to the IFC standard.

The exportation was performed using the "IFC-EXPORTER" Plug-in from inside the Revit Architecture, by the settings of the version "IFC 2x3 Concept Design BIM 2010".

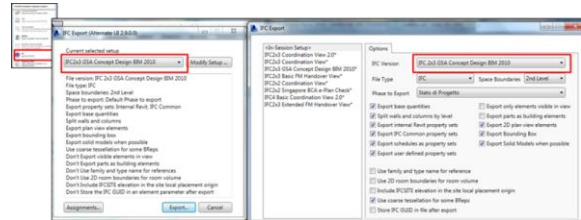


Fig. 5 – Parameters settings for .ifc file generation.

After that, the generated .ifc file is verified in Solibri Model Checker. In particular, as can be seen in the following figure, the geometric dimensions defined in the BIM model and those exported in the .ifc file, relatively to the highlighted wall in Fig. 6, (in other words these parameters as "height", "length" and "width"), appears to be exported successfully.

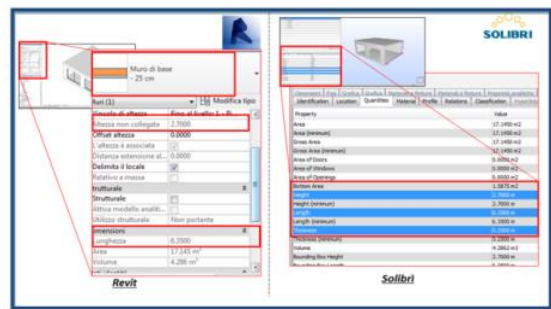


Fig. 6 – Comparison between the geometric dimensions of a defined wall in the BIM model and the ones which were written in the exported .ifc file.

Analyzing the thermal properties of the components of the envelope, it can be noticed that the thickness and the total value of the thermal transmittance of the same were exported as well as

the names and the thicknesses of the individual materials. It is not possible for the thermo-physical characteristics of each material layer (especially thermal conductivity, density, specific heat and absorption coefficients) to be exported as these represent the necessary information about the construction of a thermal model to be evaluated in dynamic state.

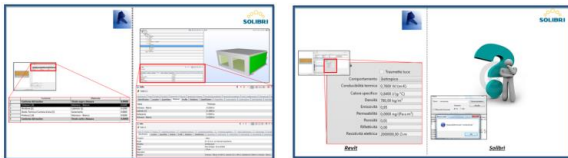


Fig. 7 – Non-response in the .ifc file about the thermo-physical properties of each material defined in the BIM model.

### 5. From .ifc to .idf file

EnergyPlus simulation engine, like many engines, can manage only its own text-file format (.idf). Therefore, even if the .ifc format is going to be the most acknowledged international standard for interoperability, the .ifc model exported by Revit should be converted into an .idf file to run a simulation on it by using EnergyPlus. In addition, as already highlighted in the previous section, in the .ifc exporting process, many thermal properties are not written. So, since the interoperability process between BIM models and .idf thermal models (by passing through .ifc standard) is not direct (Bazjanac at al., 2013), Space Boundary Tool middle-ware was used to add missing information and fixing geometry (Bazjanac, 2010). This intermediate software allows the user to convert an .ifc file to an .idf file by adding boundary conditions to thermal surfaces, fixing some geometries, and writing material thermal properties by referencing to a “library” .idf file. To automatically create this support file from the Revit model, an additional routine was developed together with One Team software house, to be added to the Addin Innovance tool. This routine can write an .idf file by copying material thermal properties used in the BIM model with the correct EnergyPlus syntax, simply by clicking on a toolbar button.

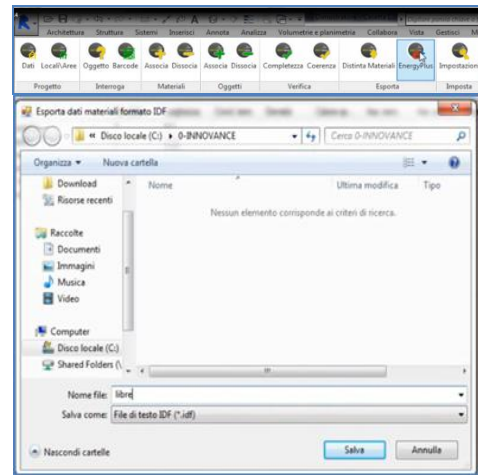


Fig. 8 – .idf library generator button in Addin InnovANCE

Then, the exported .ifc file can be processed by the Space Boundary Tool, together with the .idf library file, to obtain a first stage of the thermal model.

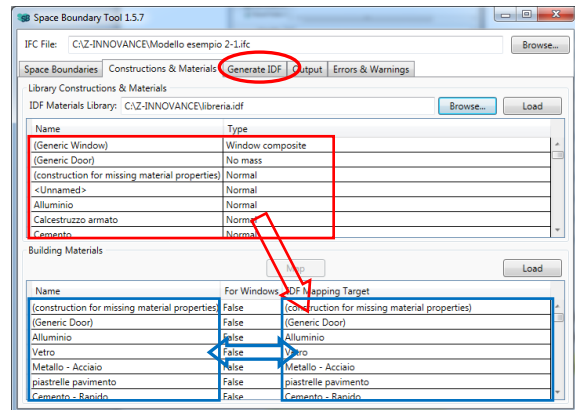


Fig. 9 – Materials thermal property assignment and .idf model generation in Space Boundary Tool.

The obtained thermal model contains information about building geometry and envelope thermal properties. User behaviour should also be added. This can be done directly by the EnergyPlus idf editor or by other EnergyPlus-based interfaces such as OpenStudio or DesignBuilder, simply by opening the .idf file. After that, the model will be ready for a first simulation to obtain energy demands.

To obtain building energy consumptions, also a mechanical system should be modelled. However, to do this, a very good knowledge of EnergyPlus is needed. Further, once the .idf model is available, many other aspects can be investigated, such as thermal comfort, by adding more EnergyPlus objects by an expert user.

## 6. Conclusion

Nowadays, it is not possible that simply by clicking on a button, a BIM model is correctly converted into a transient-state energy model and a reliable result on the building energy performance will be provided. This is mainly due to the different aims of BIM and energy models, whose approximations and rules are significantly different. Consequently, a fine checking by an expert user must always be done, to ensure the final result is accurate.

Many processes can be automated and the construction of a thermal model will be faster than starting from a blank sheet. Improving the level of automation, as this study has tried to do, will make the integration of energy evaluation in building design more affordable for design teams.

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