Building Information Modelling Capability in an Energetic Simulation Perspective

Alcínia Zita Sampaio(✉), Luís Araújo, and Eduardo Coelho

IST, Department of Civil Engineering, University of Lisbon,
Av. Rovisco Pais, Lisbon, Portugal
zita@civil.ist.utl.pt, luiscna@hotmail.com,
eduardo.oliveira.coelho@gmail.com

Abstract. During the initial project phase the decisions have a greater importance on a building, so it is necessary that different designers can use a centralized information model, allowed by Building Information Modeling (BIM) methodology. The study evaluates the capabilities of BIM on the use of precise and updated information related to the construction solutions of exterior walls and floors, throughout the management of the building life-cycle, namely, in the perspective of an energetic simulation. The work carried out involves the creation of a BIM model and the establishment of a library of parametric objects representative of current walls and floors. The information introduced in the model, together with the parameters, concerning physical proprieties, added to the walls and floor objects, are used in the development of sustainability tasks supported in the BIM model. The main advantages are identified when comparing alternative constructive solutions, and shown BIM ability to support decisions by stakeholders during the development of a project.

Keywords: BIM · Parametric modelling · Information extraction · Energetic analyses

1 Introduction

The choice of alternative solutions in a construction has a considerable effect in the budget, in the environment and for society. So it is essential to provide a quick access to the parties involved about multiple information concerning different solutions. The impact of the choice of a particular solution is normally obtained on an advanced stage and by using multiple and complex software, where only small things can be changed. Currently, BIM methodology can be used to get information associated with the multiple stages of building construction process and lifecycle management and to assist all the parties to support their decisions [1].

This study intends to evaluate the implementation of BIM to support the analyses of alternative solutions, mainly by changing walls' and roofs' type, applied in a BIM model. The study essentially estimates how the model can provide the information the designer need to prepare energetic analyses. For this purpose, the following objectives were established [2]:

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- Understand BIM's methodology based in parametric objects and how to enrich the model;
- Identify different architectural solutions based in the use of several type of walls and floors currently applied in the national market;
- Evaluate in an energetic perspective the different solutions using a Revit plugin, the Green Building Studio.

To model and extract all capabilities of BIM, it is necessary that all the parametric objects that are going to be applied in the generation of the required model are available in the BIM tool. The parametric object must contain the physical parameters required by the BIM plugins that are going to be used to obtain different type of analyses [3]. For that new parametric objects of current walls and floors were generated.

The text concerns essentially the analyses of BIM capacity when used in an energetic context. As so the parameters that compose a wall/floor-parametric object are described in details, as an answer to the BIM power concerning an energetic simulation either in the design stage and after to evaluate the energetic consume in a building in use.

2 Exterior Walls

The designer should be able to quickly access to different options of exterior walls, so the user could decide the right wall to apply. The paper considers the study of the main walls used in Portugal [4]. Therefore, a research throughout the different types of walls has been made. Although it is possible to find different systems, they must respond to environmental and people's demand. They should protect the users from outside:

- Ensure stability in case of fire;
- Safety protection in situation of earthquakes or explosions.
- Guarantee comfortable conditions adapted to the environment where they are built.

For the present study and in order to define parametric objects of walls, five common facades used in Portugal were selected (Fig. 1):

- Two solutions of double wall brickwork with a layer of air partially filled with a thermal insulator;
- A External Thermal Insulation Composite (ETIC) system, that consist of an outer insulator coated, fixed mechanically or by gluing in brick support panel;
- A ventilated facade insulated on the outside in a brick panel with ceramic tiles spaced from the insulator to allow wall ventilation;
- A Light Gauge Steel Frame (LGSF) system, constituted from interior to exterior, 2 gypsum panels for interior, insulator panels made of rock wool, OSB panel, and for exterior an insulator panel cover with mortar.

The wall, as a building component, should check a number of requirements. The application of an exterior wall depends of the physical and mechanical properties of each material that composes the different layers of a building element. So to perform multiple analyses and support decisions, it is necessary to select properties that can be

associated with parametric objects of exterior walls, to achieve an accurate database accessible to different collaborative parts.

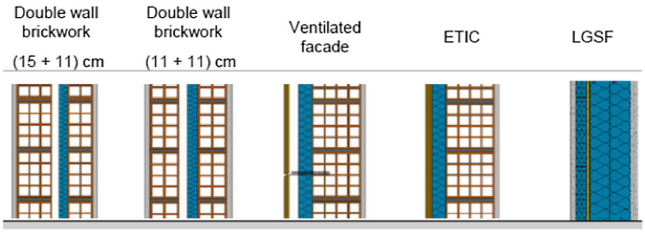


Fig. 1. Selected common facades [4].

Since the internal library of the BIM tool in use, the Revit from Autodesk [5], don't contain the main walls used in Portuguese construction it's necessary to create them. Five types of parametric objects of walls were identified and associated with a set of parameters. A Revit wall system is composed of several layers of different materials, with distinct proprieties (Fig. 2). To achieve an accurate wall it was necessary to identify materials and their properties. Revit contains some of the materials (concrete and mortar) and others were created (OSB panels or gypsum panels).

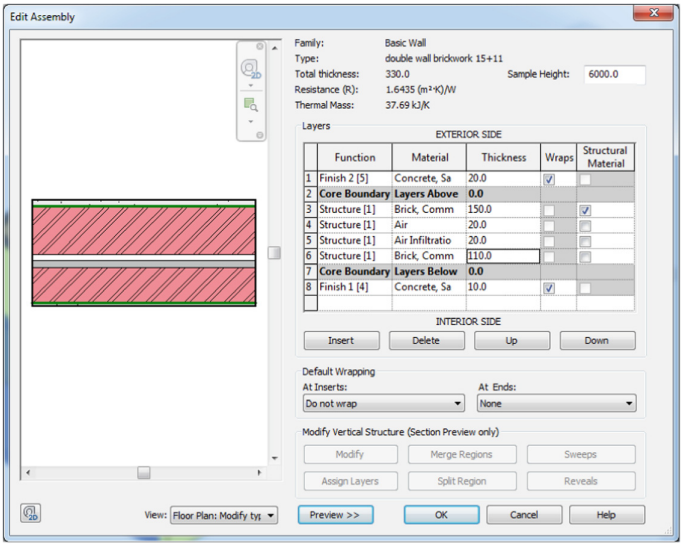


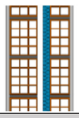
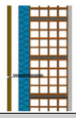
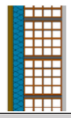
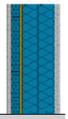
Fig. 2. Parametric object of double wall brickwork.

2.1 Physical Parameters

To generate a BIM model, the initial needs must be clearly defined, which can vary according to the stakeholders and users. The designer needs to visualize details of the project, and a client or a shipyard organizer needs a cost analysis and a project scheduling. Several types of parameters can be added to each BIM model element which enables selecting and providing cost estimates as well as material tracking and ordering. In consequence, several level of detail and level of development (LOD), in their turn can change from one user to another, and can be incremented at different stages of the building project and its occupation.

The parameters to be attached to BIM objects should consider studies such as thermal analysis and energy efficiency, construction planning, construction and maintenance costs or provide maintenance plans. In this study where considered, essentially, parameters related to the physical and mechanical properties oriented to the energetic analyses and environmental impact. Thus, the chosen parameters joint with the respective solution are physical parameters such as: thickness, superficial mass, thermal resistance or thermal transmittance; acoustic parameters, sound transmission rate due to aerial transmission or fire rate parameter; environmental parameters such as embodied primary energy. These parameters are listed in Table 1 and must be considered in each wall's parametric object when created.

Table 1. Table of parametric values for each wall type.

	brickwork (15 + 11) cm	brickwork (11 + 11) cm	Ventilated facade	ETIC	LGSF
Type of exterior wall					
Physical parameters					
Thickness (m)	0,37	0,33	0,35	0,32	0,235
Superficial mass (kg/m²)	300,84	277,64	255	261,77	86,25
Thermal resistance ((m²K)/W)	3,08	2,95	1,73	2,11	5,43
Thermal transmittance ((m²K)/W)	0,307	0,32	0,525	0,44	0,179
Economical and management parameters					
Construction cost (€/m²)	75,28	73,28	158,72	100,21	111,73
Maintenance cost (€/ano.m²)	2,75	2,75	27,1	11,70	8,94
Demolition cost (€/m²)	22,55	20,86	35,25	18,13	33,23
Man hour rate (man.hour/m²)	1,795	1,747	1	2,381	1,38
Sound parameters					
Sound proof to aerial transmission (Db)	51	50	51	50	47
Fire safety parameters					
Firerate	A1	A1	F180	E180	F60
Environmental parameters					
EPE (Kwh/m²)	201,19	181,34	214,02	164,67	141,88

2.2 Parametric Objects

The 6D and 7D dimensions of BIM model are related with lifecycle-management and sustainability analysis. Buildings are responsible for 40% of energy consumption all over the world, thus the interest to know how the building is going to behave is an information that must be quick access to the designer.

A BIM model can be exported to other programs of analysis and simulation such as eQuest, Ecotect, Green Building Studio, to perform several analyses:

- The eQuest is a building energy use analysis tool that provides professionals to perform detailed comparative analysis of building designs and technologies by applying simulation program;
- The simulation of solar energy absorbed by building surfaces is possible to be realized using Ecotect;
- The evaluation of energetic consume can be performed in Green Building Studio.

The properties used by Revit depend of the material, but the main information concerns:

- Identity (description, comments, manufacturer and model mark);
- Graphical properties (color, surface and cutting pattern and textures);
- Physical properties (young's modulus, poison's ratio, shear modulus, density and thermal expansion coefficient).

The physical proprieties of a composed parametric object like a wall is automatic obtain by Revit, when the set of material layers are chosen and established each thickness (Fig. 3). Each material has specific thermal proprieties as shown in Fig. 4 for the brick material.

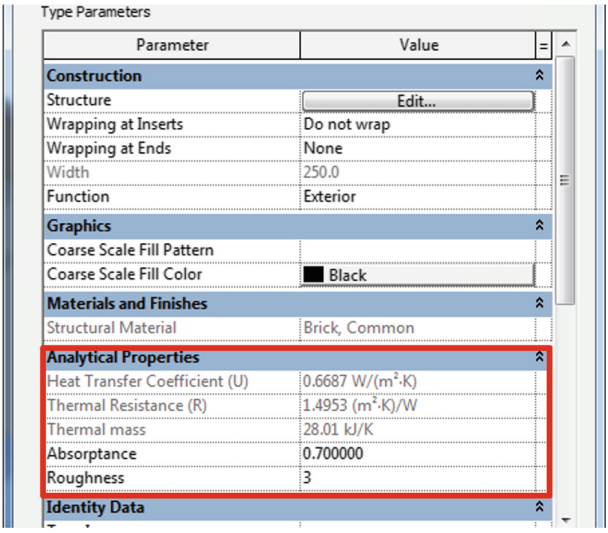


Fig. 3. Physical proprieties of a composed parametric object.

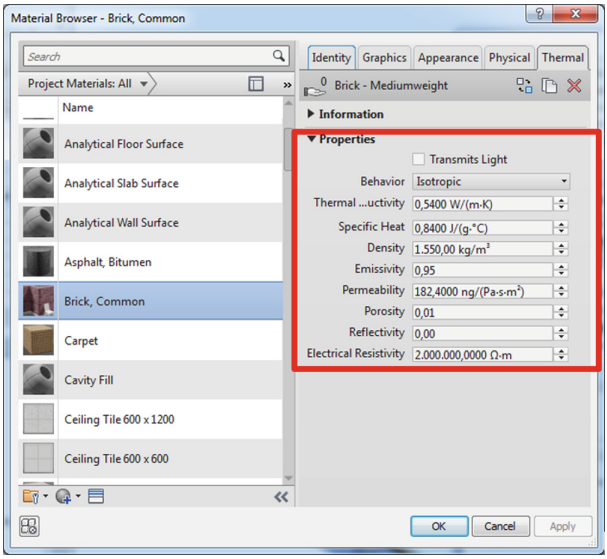


Fig. 4. Thermal proprieties of a material.

The use of an adequate BIM rich-data model, with thermal proprieties, allows the environmental and climate analysis, in design initial phases, important when comparing the environmental impact of alternative design cases. A heat analysis can be allowed before and after using thermal insulation, in a wall, and the result can clarify in relation of what solution should be used. By changing the type of wall the analyses values became distinct supporting the best solution for the project.

3 Floors

In the national market there are a large number of possible materials to be used as flooring finishing, and their selection is an important criterion to be considered by the designer. In the present study, a research about the materials commonly used in frequent building floors was done, oriented to their composition on floors and knowledge of their properties. In the scope of the work, the floor finish classification is made by type of materials (minerals, wood, textile and synthetic). It was considered the most relevant, in relation to the utilization and the traded products in the Portuguese market [6].

3.1 Physical Parameters

In order to support an appropriate selection for a constructive flooring solution in a building, its main characteristics and physical properties were identified. As one of the objectives of the study is to analyze the information that is relevant to the designer to support the decision making on different constructive solutions, this information was materialized in parameters and correspondent values and associated to the parameters

of the objects. In the aim of an energetic simulation, the parameters assigned to BIM objects were those associated with thermal and energetic analyzes. They are identical to those selected on the creation of parametric objects of walls.

On the generation of parametric objects relating to floors a set of thermal parameters, linked to each material, allows to characterize the construction solution. The thermal parameters of each solution are the basis of energy analysis that can be performed through the Revit software. So, when creating a BIM model, for the simulation of an energy analysis, the Revit software uses the thermal properties of the materials and of the construction systems. For most materials, except glass, Revit only needs to use two thermal properties [7]:

- The thermal conductivity is a property that characterizes thermally homogeneous materials or products, and represents the amount of heat, that crosses a unit thickness material, when between two flat parallel faces is established a unit of temperature difference;
- The specific heat is the energy required to rise in a temperature unit, a unit of mass.

In addition to the thermal properties and the physical-mechanical properties, it is required for an energy simulation, other thermal properties that are useful for a correct thermal characterization of materials and their constructive systems.

- The thermal resistance of a material corresponds to the difficulty of heat transmission and is determined by the ratio between the thickness of the material and its thermal conductivity;
- The thermal transmission coefficient is the amount of heat per unit of time that runs through a surface of unit area of the immersive element per unit of difference temperature between the environments that the wall separates.

3.2 Floors Objects Library

New parametric objects of floors were created incrementing the library of objects made available in the Revit system. During the definition of constructive solutions representing floors, four groups were considered based on similarity criteria between the flooring materials and the construction system components (constituent materials and their thickness). It was considered in all cases a reinforced concrete support floor. Therefore, the chosen groups are (Fig. 5):

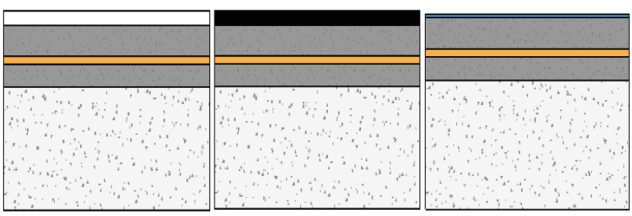


Fig. 5. Limestone, granite and vinyl floorings.

- Natural stone cladding (granite and limestone) or ceramic tiles (porcelain stoneware);
- Floating flooring made of wood, laminate or cork;
- Carpet and vinyl floorings.

Figure 6 illustrates the floating flooring made of wood constructive solutions, with the respective graphic pattern, type, thickness and function of the material of each layer (Fig. 7).

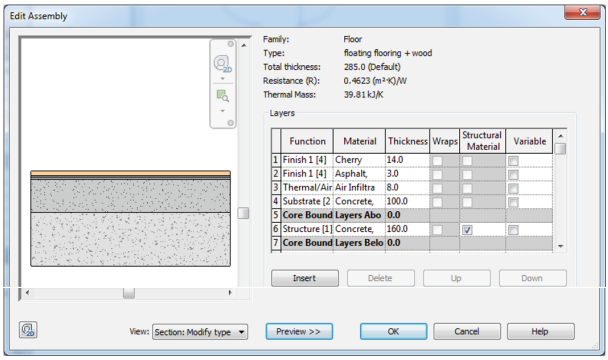


Fig. 6. Generation of a parametric object of a floor.

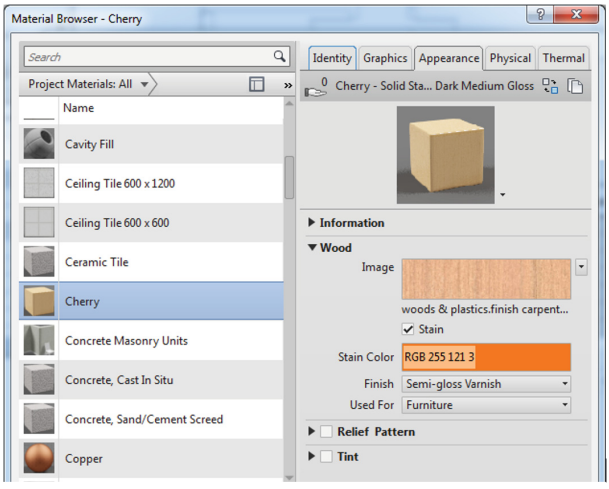


Fig. 7. Selection of a wood material.

Each floor solution is characterized by several thermal proprieties obtain from the individual features of the set of materials used in its composition (Fig. 8). When studying the type of floor to apply in a project, Revit allows the user to easily change

the type of floor. By selecting an alternative floor option, through another parametric object choose, the result of the process is immediately visualized (Fig. 9). It is possible to observe in a cut 3D perspective, the graphic impact of the floor and the user can consult the proprieties of each floor option.

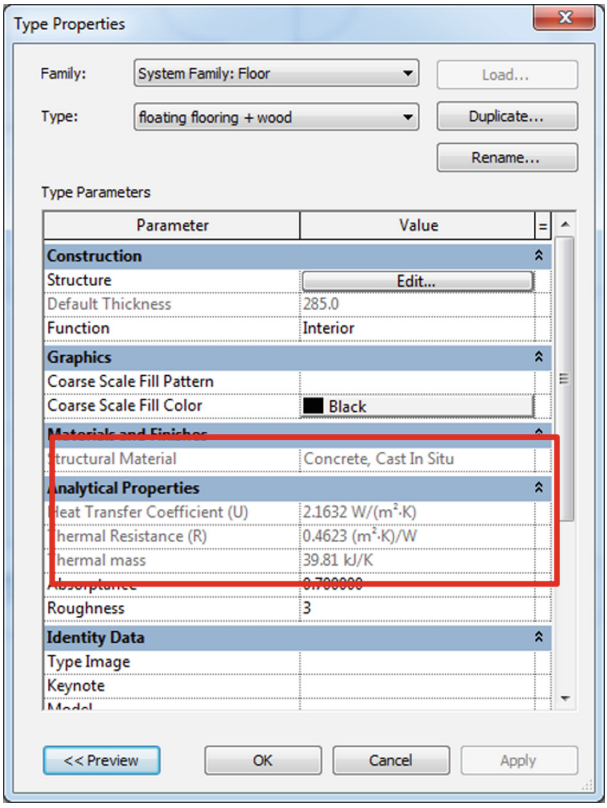


Fig. 8. Generation of a parametric object of a floor.

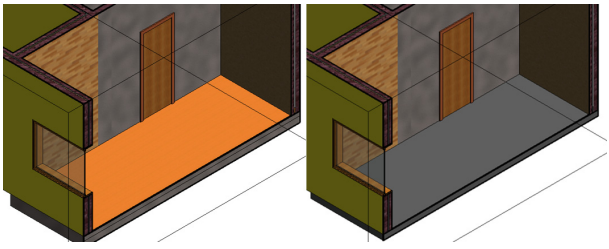


Fig. 9. Changing the type of the applied floor.

4 Energy Analysis and Sustainability

The sustainability analysis of a project considers, not only the environment aspects, but also a variety of impacts agents [7]. Sustainable development has been growing in prominence with the increase of buildings life-cycle and, consequently, the buildings management and maintenance. The BIM solutions bring an easier way for sustainable development practices by enabling architects and engineers to accurately visualize, simulate, and analyze the project in the preliminary stages, achieving more sustainable projects and reducing constructions time and costs.

Thermal insulation of building components leads to reduce the total thermal energy consumption and to accomplish a significant reduction of CO_2 emissions [8]. Special attention must be given to structural systems, concrete beams and lintels which act as thermal bridges providing poor insulation. In addition, consideration should be directed for exposure and durability. A well-insulated home can prevent to 70% of all heat flow through the ceiling, walls, and floors [8].

According to UK Green Building Council [9], the construction operations account about 40% of global energy consumption and 30% of carbon gases emissions that cause the greenhouse effect. The energy sustainability analysis of a model can be included in the 6D/BIM designation. To obtain the environmental behavior simulation, Revit can make an energetic model simulation, also allowing its transfer, directly or through an IFC file, to other energy analysis software.

It is in the designer's interest to know the tools that can support the decision-making regarding the environmental impacts that the project will create, since one of the factors to be considered in the selection of a certain constructive system is its impact on the building's energy consumption. While granting the required comfort conditions, the building should have the least energy consumption possible.

Hence Revit software has an application, Green Building Studio, capable of performing energy simulations on the 3D/BIM model, retrieving an environmental behavior simulation of the building in different project stages. Autodesk Green Building Studio (Fig. 10) is a flexible cloud-based service that allows the user to run building performance simulations to optimize energy efficiency and to work toward carbon neutrality earlier in the design process. The plugin can be used as a standalone web service [10].

Fig. 10. Autodesk Green Building Studio a Revit plugin.

In the present work an energy and thermal analysis was carried out. The properties values necessary to the floors constructive solutions were studied and indicated in order to perform such an operation. For an analysis concerning a study phase, the 3D model

can be presented as a conceptual mass, but for analyses with more advanced features, is necessary to give more detail to the constructive elements.

After the required settings are included in the model, it is transferred t for analysis in a cloud, an Autodesk platform. The analysis is performed and a final report is created (Fig. 11).

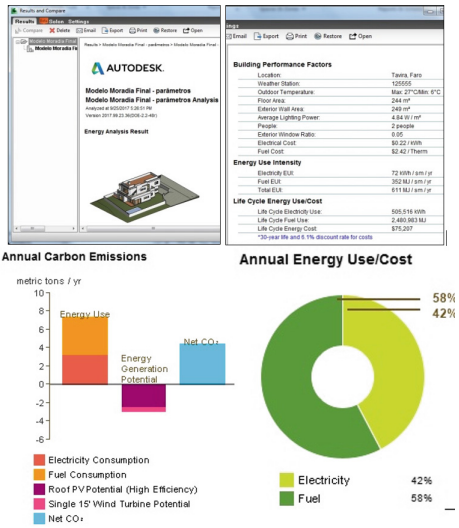


Fig. 11. Energetic analyses report.

BIM-enabled design process necessitates innovative methods for design thinking and representation that architects and engineers used to apply and utilize. BIM is a decision-making tool for evaluating environmental factors in conceptual designing, rather than a sole tool for designing. BIM tools allow integrating several settings, in which the target is to improve the environmental and climate-response factors. The thermal parameters of walls and floors objects were used by Revit plugins to obtain results and allowing comparing different solutions. Just the walls and floors were defined with detail, but other elements (light systems or windows) should contain identical thermal parametric to be used in an energetic simulations.

Green Building Studio uses a simulator (DOE-2 simulation engine) to estimate the energy use of construction and operating costs, and it is based on the effects and interactions of the building materials, systems, level of use and climate. This application dynamically analyzes the whole building heat and energy levels, and is based on the recommendations. *Leadership in Energy and Environmental Design* (LEED) [11].

A model more complete with light systems allows to perform a deeper sustainability analyses. After setting up thermal properties of all building components: walls, doors, windows, and roof; the Revit model is exported to a cloud. Next, the geographic location is selected and in Green Building Studio the model opening. Several analyses can then be required: energy and carbon results, water usage, photovoltaic analysis, and

LEED [11] daylight (Fig. 12). Alternative solutions can be generated and tested using the energetic Revit plugin as it easily tracks several types of environmental results of the design alternative, supporting the comparison of solutions in what energy and sustainability concerns.

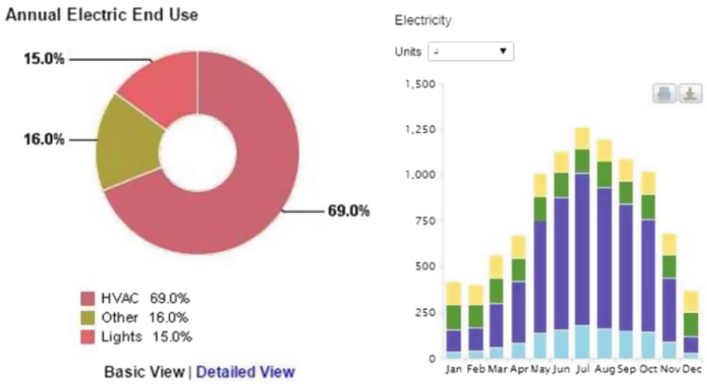


Fig. 12. Green Building Studio graphics of electric end use.

So the goal is to recognize that the innovative methodology that currently became "mandatory" in all sectors of the construction industry, can bring also advantages when simulating energetic consume along a building life-cycle. As the used software is Revit, from Autodesk, the Revit plugin most adequate to be applied in the energetic simulation in naturally the Green Building Studio. That's way just this software was used. In the future, and in order to improve scientifically the study, other BIM model in IFC universal format can be used and tested confronting those results to the present study.

5 Conclusions

BIM would benefit the design process particularly in the area of BIM sustainability application with effective impact during designing. With the increasing global awareness of improving the environmental factors of building performance and the needs of achieving the climate-responsive design, the BIM use associated with environmental analysis of related computer programs appears as the primary key in architectural designing.

The study describes the capacity of BIM to compare solutions supported in energy analyses results, mainly oriented to two principal building components: exterior walls and floors. The characterization of current type of these building components was done and the correspondent parametric objects were created. A set of physical and mechanical proprieties, of materials and construction systems, were identified and selected as of interests to be used in energy simulation tools.

In the study of alternative solutions, decision-making can be grounded using a comparative analysis of the results relating to environmental performance and

contribution to the reduction of carbon dioxide emissions allowed by Green Building Studio tool. Environmental building performance can be improved by applying a Revit plugin, Green Building Studio, which gives a wide of sustainability analyses obtained directly from a BIM model. Consequently, architects can easily include environmental design principles in conceptual designing, starting from the proposition and the composition of architectural spaces and forms.

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