
AN ASSISTANT FOR THE DESIGN OF POSITIVE ENERGY BUILDINGS

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ABSTRACT

Modern building simulation programs require the user to master a huge variety of IT skills, multi-disciplinary vocabulary and proprietary technology. In addition to these technical problems, hypotheses must be defined concerning the granularity of the simulation model, domains covered, phenomena taken into account, as well as the desired accuracy. Due to this complexity, building professionals often refrain from using advanced building performance evaluation tools.

The goal of the Assistant for the Design of Positive Energy Buildings is to present a simplified view of the simulation tool to the user. The assistant, or ‘wizard’, is able to generate a building simulation project from a reduced set of parameters and allows the user to enrich this information as it becomes available.

At the same time, the Assistant is linked to a Building Information Model (BIM) software. This 3D model is used to automatically generate a building description which contains adjacencies between all spaces defining the building. The assistant is then used to complete the building description and its equipment in a user friendly graphical interface. It is also possible to generate a complete simulation project from the simplified view, thus making all options of the underlying simulation tool available to expert users.

Keywords: Dynamic simulation, Energy Savings, Positive Energy Buildings, BIM, design process, IFC, ICT

1. INTRODUCTION

Transient simulation of the energetic behavior of buildings has become a best practice in most industrialized countries. Specialized companies now offer simulation services using complex tools like TRNSYS Simulation Studio (Klein et al. 2009). Although these tools have gone a long way towards user friendliness, they still face two major problems:

1. although powerful graphical user interfaces are now available, the underlying modeling concepts the user must understand for a reasonable use remain complex. The expertise needed requires an expert of the application domain, who needs to acquire and maintain modeling skills.
2. The description of the building envelop is a complex, time consuming task, which induces cost and effort small consulting companies cannot afford for every day project work.

This article describes an approach which tries to address these problems by introducing

1. A template-based, simplified graphical user interface, able to generate complete simulation projects, based on a reduced set of input parameters.

2. A graphical building viewer based on the IFC format, able to import building descriptions, display them and export them to simulation software.

2. GOALS OF THE ASSISTANT

2.1 Facilitating the access to building simulation tools for non-experts

The primary goal of the assistant for the design of positive energy buildings is to simplify the use of existing building simulation tools for non-experienced users. This is achieved by presenting a simplified view of the simulation tool to the user. The assistant, or 'wizard', is able to generate a building simulation project from a reduced set of parameters and allows the user to enrich this information as it becomes available.

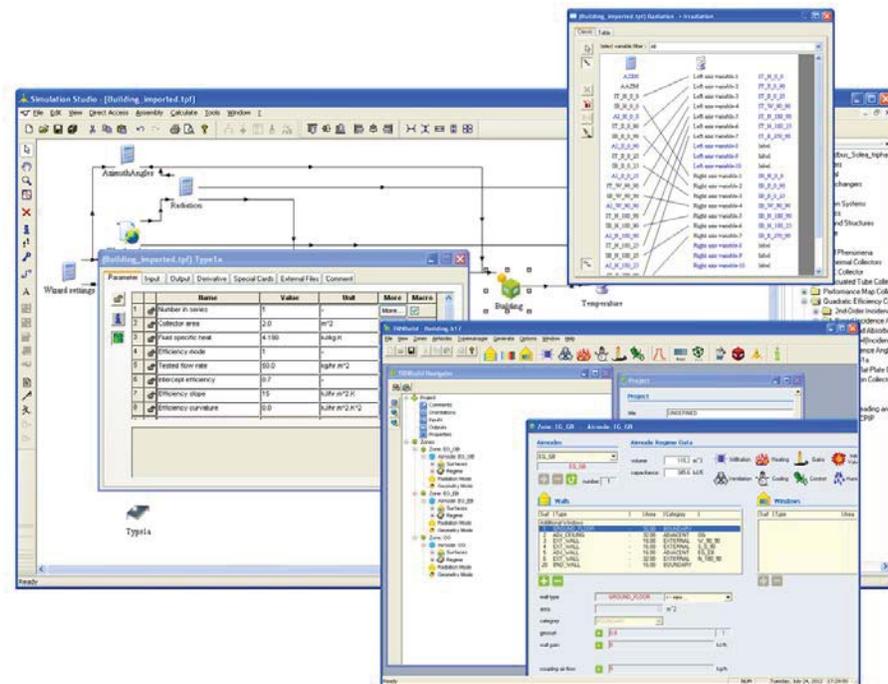


Figure 1: Example of a building project set up manually in the full simulation environment

The design of such a simplified view involves two major steps, both equally important (Nassiopoulos et al. 2008): (i) choosing the domain of application of the software and (ii) designing a graphical user interface with appropriate interaction modes allowing the user to communicate with the software.

The first step consisted of choosing a set of appropriate hypotheses, defining the granularity of the simulation model, domains covered, phenomena taken into account, as well as the desired accuracy. For this purpose, a study was conducted by the consulting company *TEP2E*, experts in thermal building simulation. The goal of this study was to define the working domain of the software, define major hypothesis with respect to the French legal context (mainly thermal regulation) and define best practices. The tool is destined to the French market. It was also decided to restrict the first version of the assistant to residential buildings. Industrial buildings are not covered. The main domains taken into account were defined as:

- *Weather*
- *Usage*
- *Envelope & openings*

- Heating and domestic hot water production
- Solar domestic hot water systems
- Cooling systems
- Ventilation systems
- Furnaces
- Auxiliaries
- Lighting
- Production of electricity (photovoltaic)
- Gains

In addition to a set of guidelines, this study also produced template projects built for TRNSYS Simulation Studio, implementing the major types of projects conducted by a typical, French consulting company. The simulation projects were merged into one, parameterized simulation project allowing to produce all phenomena targeted by the assistant, using approximately 300 variables. This directly defines the physical phenomena taken into account, as seen by a typical consulting company.

The second step consisted of designing a graphical user interface and adapted interaction modes with the user. We choose a ‘wizard’ style window based on tabs, each tab representing one of the main domains treated by the software. The user is led through the design process step by step, and can return to previous steps at any time.

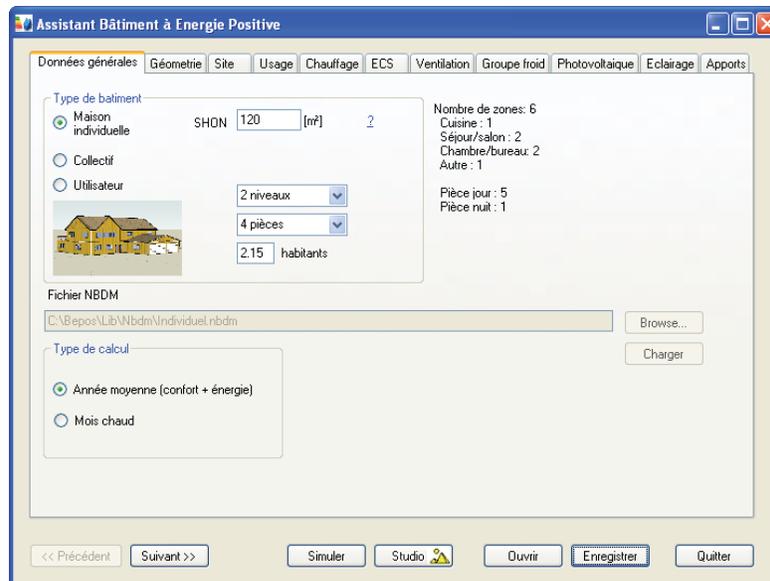


Figure 2: The simplified view of the assistant

The most difficult and time consuming part in defining a multi zone building simulation project is the definition of the envelope and its structure: the user has to define the thermal zones making up the building, which form an adjacency graph together with the walls delimiting these zones. Modern simulation tools such as TRNSYS 17 allow for a data input using a 3D building editor. This input method is, however, too complicated and time consuming for the typical, ‘small’ consulting company doing a standard project. At the same time, some studies might require a more detailed approach using 3D data (Soubra et al. 2009 & 2011). Therefore, 2 levels of complexity are proposed to the user. The simplest level is to use one of the two template buildings provided: single-family house and a multi-family building. Once the template chosen, the user can modify it by scaling it, or by adding and removing zones, walls, windows, etc., in a tree editor. On the advanced level, the user can import a NBDM (Keilholz et al. 2008) data file describing the detailed envelop structure.

2.2 Facilitating communication with the experts

A secondary goal of the assistant is to simplify communication with experts in building simulation. Typically, a small consulting company or architect will make a primary study and come across a problem or phenomenon which it finds hard to evaluate – often involving innovative technology or designs. The assistant will allow to make a first estimation concerning the impact of the domain of interest on the overall performance of the building. This helps the user to decide if a detailed simulation study, conducted by a specialist, is appropriate.

2.3 Examples of dialogs

Examples of simplified user interaction are shown in figure 3. The steps shown are the definition of usage values (step 4) and heating (step 5). In step 4, the user can define profiles for occupation during day and night time. To define these profiles, an interactive histogram editor can be used. In addition to this, two holiday periods can be defined. Also, the parameters for the control strategy of the solar protections can be defined: thresholds for temperature and radiation required to close solar protections, the maximum shading factor and maximum solar incidence angle.

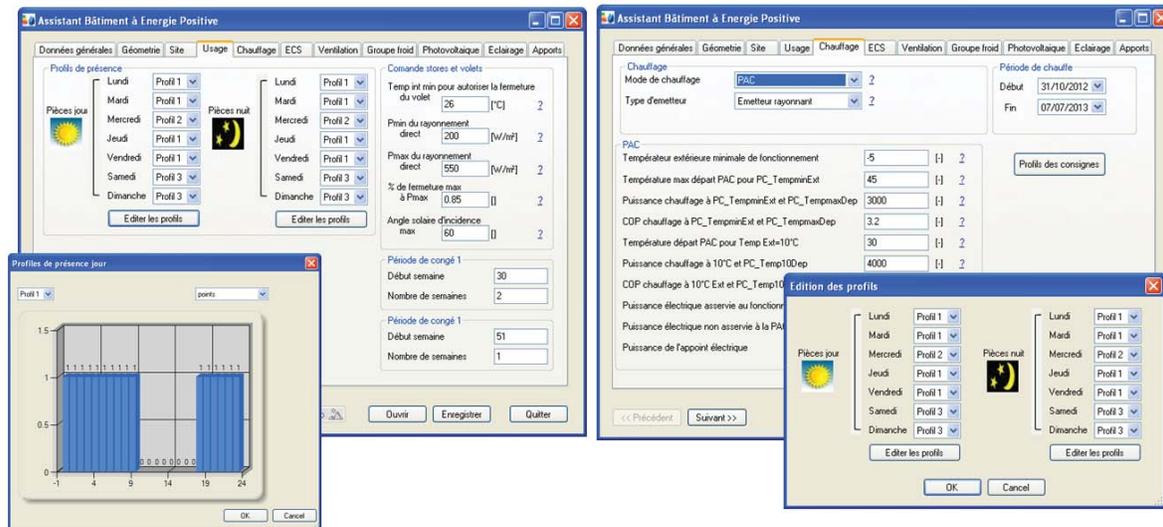


Figure 3: The simplified view of the assistant

This dialog on the right shows how the user defines the heating system. First, the type of heating is chosen from a list: no heating, convective electrical heating, electric furnace, gas furnace or heat pump. Depending on this choice, additional parameters may be added to the dialog. In the example depicted in figure 3, 'heat pump' (PAC in French) has been chosen. As a consequence, the parameters required by the heat pump model appear. A heating period as well as daily heating profiles can also be defined – one per week day and separately for day and night use.

2.4 Results produced by the software

The direct results produced by the assistant include yearly curves of key variables for each domain modeled, as well as a global evaluation of heating and cooling energy consumption of the building. This evaluation is given in the form of a mark, ranging from G (more than 450 kWh/m²) to A (less than 50 kWh/m²).

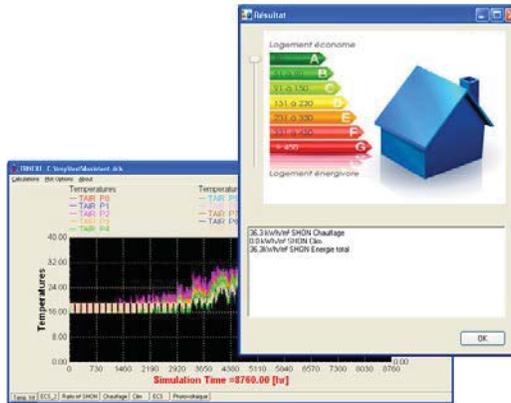


Figure 4: Default results produced by the assistant

These results produced by the assistant can be used to compare the simulated building to other variants, varying system and / or building design. That way, energy savings can be achieved by optimizing the design and choosing the best Solution.

Another way to use the results obtained by the assistant is to communicating with a building simulation expert. Such experts will have to refine and adapt the simulation, and to do so, they would normally have to input the entire problem again in their simulation environment. Thanks to the assistants export function, the problem can be handed over to an expert as a filled-in template simulation project. Just like the first-level user is able to use templates to describe his problem, the expert user – be he/she in house or in an external company - can open such a project in the complete simulation environment. This not only simplifies the communication with the expert – it also saves a lot of time, because the simulation project does not have to be set up from scratch.

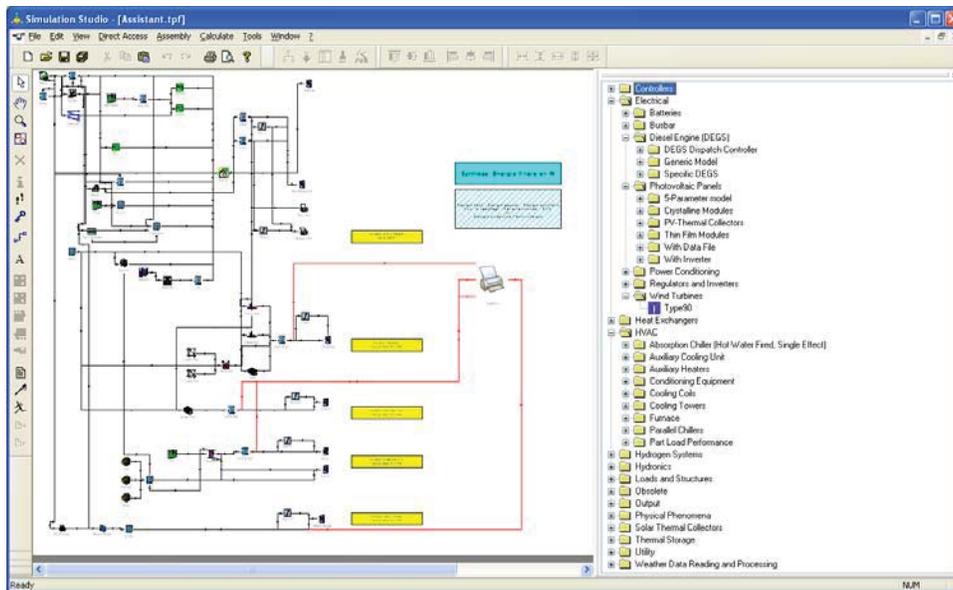


Figure 5: The generated simulation project from fig. 2 in the full TRNSYS environment

The generated simulation project contains all data entered by the first-level user, including a building description based on either one of the building templates or the NBDM file chosen by the user. All TRNSYS component models corresponding to any domain that can be addressed by the assistant are included, even if the first-level user has deactivated them. For example, if the user has decided against photovoltaic panels, the photovoltaic panel component still appears in the assembly, but with an

evaluation factor of zero – it has no effect. This simplifies the design of variants, as components can simply be ‘switched on’ by changing a value. Of course, new models can be added to the project without any limitation.

2.5 Coupling with a BIM

A very important aspect of the simulation project definition is the building description, both in terms of volume (the amount of data the user has to input) and impact on the results. To address this problem, the assistant proposes building templates for single and multi-family houses, as well as the possibility to import NBDM files for more detailed studies, where the optimization of the building itself (as opposed to the system) is in the centre of the study. Unfortunately, NBDM files can not currently be generated directly by any user friendly 3D modelers. Therefore, the Assistant is also linked to a Building Information Model (BIM) software.

BIM plays a key role in interoperability since it allows for the creation and use of coordinated, consistent, computable information about a building project in design, construction and building operation and management. IFC (Industry Foundation Classes) emerged as the major standard for BIM implementation in the scope of construction industry information exchange. Its development is the result of an industry consensus building process over several years and across many countries. IFC contains common agreements on the content, structure and constraints of information to be used and exchanged by several participants in construction and facilities management projects using different software applications. The result is a single, integrated information model representing the common exchange requirements among software applications used in construction and facilities management specific processes. It is currently registered with ISO as a Publicly Accessible Specification (ISO16739). Mainstream CAD applications such as Revit, Bentley, ArchiCAD and similar implement BIM / IFC import and export functions.

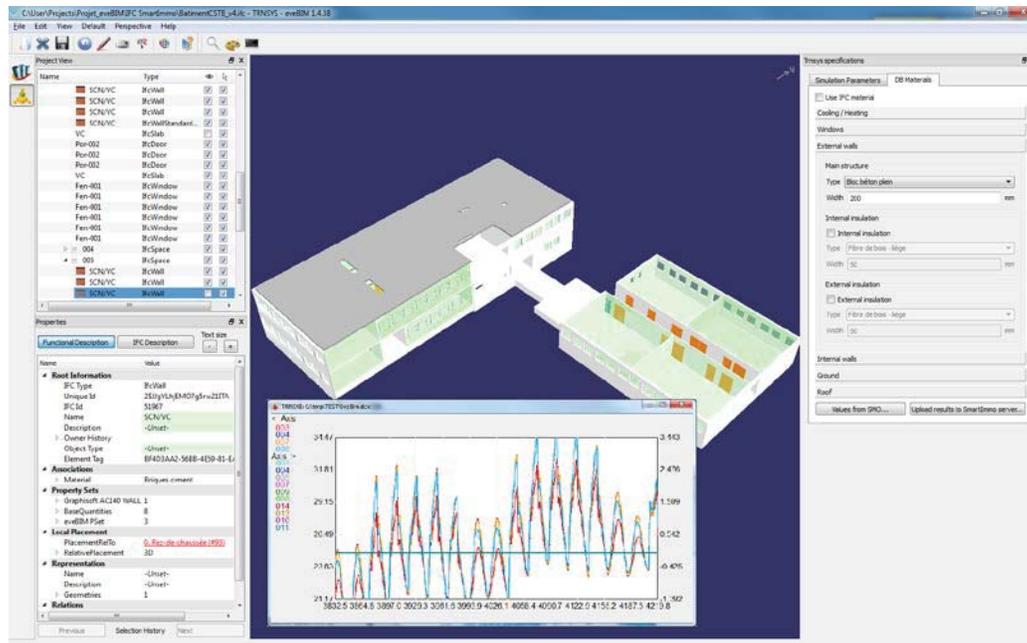


Figure 6: EveBIM displays IFC files in a 3D viewer, and exports data to simulation tools

EveBIM allows to transform IFC files into 3D information and display the building it describes. This 3D model is then used to automatically generate a building description which contains adjacencies between all spaces defining the building. After that, the assistant is used to complete the building description and its equipment using its step by step graphical user interface.

IFC format handles physical properties describing thermal performances of building insulation and walls. These properties can be exported to the simulation engine in order to compute building performance. Knowing the lack of possibilities of 3D software to generate IFC files containing physical properties (Thermal conductivity, Specific heat capacity, Thermal resistance) a database has been setup in order to complete files not containing all required information. This database contains standard walls components like concrete or cellular bricks and insulation like wood fiber or cellulose.

This version of the software also includes automatic recognition of equipment involved in solar domestic hot water installations. As seen in figure 7, the different elements are solar collectors, tanks, pipes, heating devices and pumps.

These elements can then be completed by exporting the generated file to the simulation engine and adapting the physical model used to compute results. In this case, the building description is used to obtain the type of use and the global area of the building. Using this values, we are able to automatically generate useful scenarios of hot water demand.

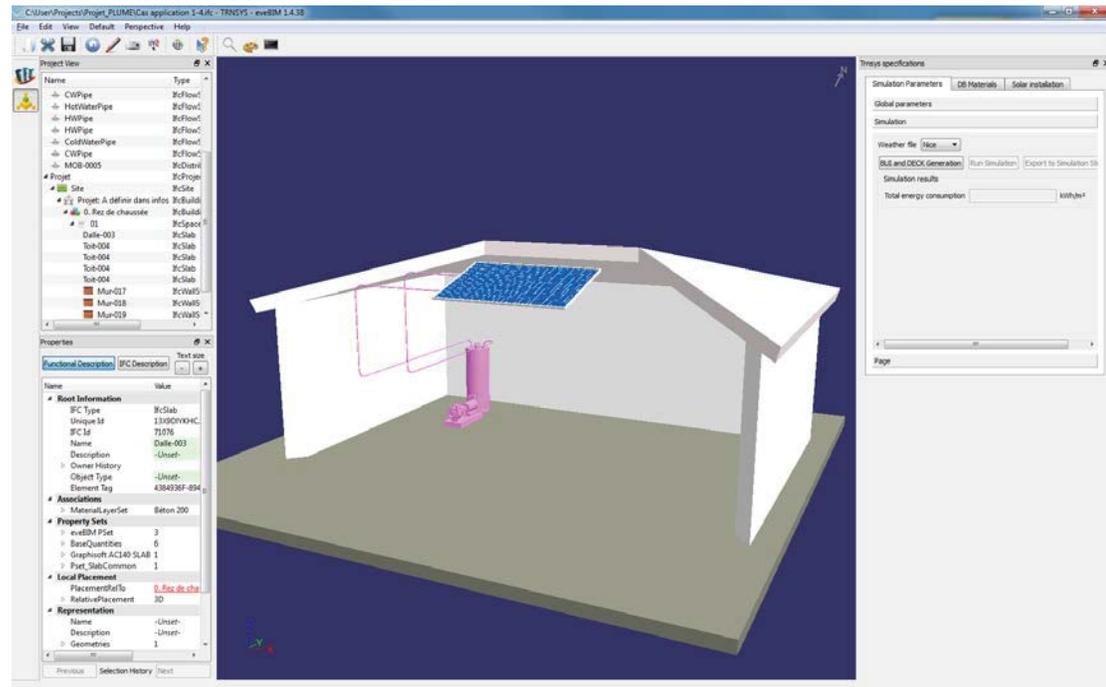


Figure 7: EveBIM exports solar equipment data to simulation tools

3. CONCLUSION AND FUTURE WORK

This paper has described an approach to simulation for non-experts, allowing to use complex simulation tools in a simplified, easy to use graphical environment based on templates. The templates take constraints specific to France into account, such as the legal context and common best practices. This environment, called ‘assistant’, is able to produce complete TRNSYS building simulation projects, as well as run and analyze them. Expert users have full access to the generated projects in the form of normal TRNSYS Simulation Studio projects. The EveBIM IFC viewer has been connected to the assistant as a preprocessor.

Future work will include a tighter integration of the assistant’s graphical user interface into EveBIM. One drawback of the current solution is the fact that any modifications made in the assistant can be translated to a new TRNSYS simulation project, but they are lost for the EveBIM project – it is not possible to ‘go back’ to the EveBIM environment. A full integration of the assistant would mean that the complete interface of the assistant would be available as part of the graphical interface of EveBIM, and that all data

(3D building description + assistant data) could be saved together. The user would then only have to leave EveBIM in order to work with the full TRNSYS simulation project.

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