SIMEB: SIMPLIFIED INTERFACE TO DOE2 AND ENERGYPLUS - A USER’S PERSPECTIVE – CASE STUDY OF AN EXISTING BUILDING

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ABSTRACT
SIMEB is a freely distributed simplified common interface for DOE2.1E, DOE2.2 and EnergyPlus.

Potential applications are: energy saving assessment, diagnostic tool for (re)commissioning, new building design, code compliance, energy saving potential assessment for estate stock. The market expected: free, user-friendliness, flexible in terms of building description complexity, compatible with others, suitable for program certification.

The SIMEB features (archetype buildings, assisted calibration, clustering analysis, multibuilding interface, interoperability with EQuest, Google Sketchup) and potential applications are presented.

The integrated process and a case study using DOE2.1E, DOE2.2 and Energy Plus are presented and compared to AMR using the built-in tools.

INTRODUCTION
In the Province of Québec (Canada), the electric utility (Hydro-Québec) was mandated by the regulators to design an energy efficiency program with ambitious energy saving targets (4.5 TWh by 2009, 5.8 TWh by 2010 and 11 TWh by 2015 over a total annual consumption of 167.6 TWh in 2010) (Hydro-Québec, 2009). Buildings account for 20% of the overall electricity consumption in Québec. It is demonstrated that global building optimization leads to major energy savings and building simulation is a must toward that path.

As part of its energy efficiency program, Hydro-Québec put in place an initiative to develop and support tools to promote a market transformation toward the use of building energy simulation to improve the energy efficiency of buildings.

This paper presents the approach that led to the SIMEB software, a short description of its features and a Case Study. The SIMEB software is a freely distributed and common interface for the DOE2.1E, DOE2.2 and EnergyPlus calculation engines. As this paper is more focused on the applications and case study of SIMEB software, the reader is invited to read the papers cited in the references for more technical details of the SIMEB features.

Background
In 2003, Hydro-Québec launched an incentive program for energy efficiency for new and existing commercial buildings. The program's subsidy calculator (PEP) uses DOE2.1E simulations of a proposed building and a reference building. The subsidy is based on the energy difference between these two simulations. This approach is still used in 2011 in the Hydro-Québec incentive program (Hydro-Québec, 2011) and over 1500 applications have been put into effect since 2004.

The easy to use PEP interface which integrates a simplified zoning definition has been largely adopted on the market as a result of to the incentive program.

Over a short period of time, PEP users realized the opportunity provided by this software as a starting point to conduct DOE2.1E simulations for different purposes such as: energy saving assessment after retrofit, a diagnostic tool for (re)commissioning, new building design, code compliance, energy saving potential assessment for estate stock. For those tasks, these users were looking for tools that were: free, easy to learn and use, flexible in terms of building description complexity, compatible with others, suitable for program certification (LEED and others). Hydro-Québec decided to go beyond its incentive program's subsidy calculator and SIMEB was born. The tools and features of SIMEB were developed trying to address those issues.

In the building energy simulation community, particular focus is put on NZEB, even though existing buildings will account for most of the energy consumption and at the same time for the biggest energy saving potential for the next decades. The development of SIMEB was oriented on new and existing buildings, taking advantage of automatic meter readings (AMR) which are increasingly available and help to improve the simulation model.
To support and promote SIMEB for a market transformation, Hydro-Québec set up a website (Hydro-Québec, 2010) including weather data files, a helpdesk and newsgroup. As part of a collaborative effort with universities, Hydro-Québec delivered training to engineering students and some professors use SIMEB as a tool to teach building simulation.

The next sections shortly present the features of SIMEB and their suggested applications towards improving the energy efficiency in buildings.

**Variable Complexity Interface**

Based on the user’s need, the SIMEB interface can include different levels of detail. The archetype wizard, the regular SIMEB interface and the input files are the three increasing levels of detail used to obtain a more relevant building model.

The interface is common for all three calculation engines and, in all cases, the result is based on a full DOE2.2 or E+ input file. Furthermore, the user can directly change parameters that are not accessible in the SIMEB interface in the DOE2.2 or E+ input files, save it as different building, run it, visualize the results and compare them with other simulations within the SIMEB environment.

The simple interface will attract beginners and users who are looking for a quick evaluation of the impact of an equipment retrofit of their building. More advanced users can use SIMEB, the simplified interface, to roughly fill the parameter values, cut the input time and refine the model in the input file. The user boards the train where he wants and leaves when he gets satisfactory results.

**Multibuilding Interface**

The SIMEB interface allows graphical and report comparisons of different building simulations. These simulations could be versions of the same building where energy efficiency retrofit measures were undertaken, using different weather data files, with different parameter values (calibrated or parametric studies), the reference case for code compliance or using different calculation engines (DOE2.1, DOE2.2, E+). The weather data files and meter readings are also shown and available in the interface.

**Weather Data Server**

The keystone for the simulation of an existing building is the real weather data files for the building. Calibration, recommissioning and energy saving assessment rely on reliable, available weather data files. The SIMEB (Hydro-Québec, 2010) website automatically offers real hourly weather data files for more than 50 areas in Québec (Canada) from January 1, 1995 till now. Different downloading formats are available, in Text, DOE2, EnergyPlus and SIMEB. The SIMEB format (*.swdf) is an XML file, which includes weather data files in both EnergyPlus and DOE2 formats. This allows to launch simulations simultaneously with two calculation engines.

**Archetype Buildings**

The archetype feature is a functionality generating simulations of commercial and institutional buildings with the representative characteristics of a real estate stock in Québec. The functionality requires very little information: the main building activity, the floor area and the construction year of the building. With these inputs, the physical and operational characteristics (R-value of the envelope, type of windows, type of HVAC, system controls, schedules, type of activities, etc.) are statistically extracted from a database and transmitted to the input fields of SIMEB. SIMEB creates a detailed input file (DOE2.x or E+). This feature is described in detail in (Sansregret et al., 2009).

This feature could be used to easily and rapidly provide all the parameter values for detailed simulations. This description can be used for the early stage design of a new building, the technology assessment for different building activities, a rough estimate of energy saving for retrofit measures on a specific building or as a function of building activity. The user can further refine the simulation by changing these default values in the detailed SIMEB interface.

**Assisted Calibration**

This feature assists the software user in the calibration process using monthly utility bills (electricity, oil and gas) (Lavigne, 2009), built-in engineering rules as well as optimization algorithms.

In future SIMEB versions, hourly metered data of typical days will be used to calibrate parameter values and schedules (Daoud et al., 2011). The typical days will be determined by the clustering analysis method. This feature will be for existing buildings with hourly metered data.

Building simulation must be calibrated to fit the customer’s bills to properly evaluate and assess the savings brought on by measures. Also, in the process of calibrating a building, the user often troubleshoots some building control strategies or faulty components. Residual discrepancies in the calibration process can help pinpoint sub-metering needs to troubleshoot a faulty component or control strategy. The assisted calibration feature can then be used as a: benchmark tool, retrofit assessment tool or (re)commissioning tool.
Clustering Analysis
The algorithm groups daily load profiles based on their shape in order to produce a reduced set of typical profiles. The visualization tool shows the building’s typical profiles and their distribution throughout the year (Fournier et al., 2010).

This feature can be used for the simulation results of new or existing buildings and for existing buildings with metered data on an hourly or sub-hourly basis (AMR). The visualization of simulated results can help validate simulation inputs; in particular the parameter values, schedules and control strategies to better calibrate the model. The visualization of metered data can help to detect defective components or control strategies.

Interoperability with other Software Applications
One the major concerns of the users is the software's interoperability with other software applications, which reduces time and risk of error in the input data.

For the DOE2.1 engine, the user only has to specify wall area and azimuth. In specifying a building's geometry, the SIMEB user may define functional zones and let the internal algorithm split in thermal zones or directly define the thermal zones.

As for the DOE2.2 and E+ engines, the relation between walls and zones has to be defined which asks for a formal and detailed geometry description. SIMEB proposes a wizard for a simplified, standard geometry definition of the thermal zones. For more complex geometries, SIMEB can import geometry directly from an “idf” file. This “idf” file can be produced with other software applications such as “Google Sketchup”.

SIMEB's capacity to produce, export and import native input data files such as DOE2.1, DOE2.2 and E+ opens interoperability with other software applications that use the same standard files. As an example, the DOE2.2 input data file produced by SIMEB can be opened by EQuest, then re-imported, run and post-processed in SIMEB. SIMEB can then be used to rapidly define a building to be imported in EQuest for code compliance.

Multiengine
With a standard common interface for the three calculation engines, SIMEB offers the opportunity to present and compare results in a standard, uniform format. Some standard work-arounds have been implemented for DOE2.1 and DOE2.2, but some features are only present in E+. Upon the choice of the DOE2.1 or DOE2.2 calculation engines, some advanced features are unavailable to the user in the interface. More specific detailed features that are not available in the SIMEB interface can be added or modified directly in the input file to take advantage of all the features of the calculation engines.

The user might want to use former engines for faster calculation times and rough estimates. The newer one will support more cutting edge technologies and more accurate results.

CASE STUDY
This Case Study presents the energy efficiency assessment of a building conducted with the built-in tools of the SIMEB interface. The purpose of the Study was to conduct a simulation of the building with SIMEB, compare the results with the building's real performance and then provide recommendations on the building's operations. For the time being, a series of simulations and calibrations were performed and a sub-metering campaign is now underway to provide a detailed analysis of the observed differences.

The building under study is a newly-built office building. The simulation was performed based on three levels of detail, a simplified simulation with the DOE2.1 engine, a simplified simulation with EnergyPlus and an advanced simulation with EnergyPlus. The three simulations were directly calibrated with SIMEB based on the building's monthly and global electricity consumption registered every 15 minutes by the building's meter.

Building description
The 4-storey, 5,700 m² office building is the head office of an international company located in Montreal, Canada. It was built in 2006 based on high energy efficiency standards and achieved LEED-Canada's Gold certification in June of 2010.

Figure 1 is a schematic drawing of the building drawn with Google Sketchup. Fenestration represents approximately 30% of the external walls surface. There is a central atrium, close to 2,700 m² of office space, an underground parking area, a cafeteria with a commercial kitchen and a few workshops and storage rooms.
The central atrium acts as the building's “lungs”, where an air handling unit injects 9,000 PCM of outside air. Ducted transfer fans supply air to each of the building's floors by way of the atrium. Heating of the surrounding spaces is provided by a network of radiant flooring. The building is equipped with over 40 fan coils and hydronic heaters. Fourteen heat pumps regulate the water supply and draw or reject their energy by way of a geothermal loop of 29 vertical wells. A sand-based thermal storage tank allows hot water to be stored to avoid a peak demand on winter mornings when the building's operations start. No fuels are used to heat the building.

The building's annual electricity consumption was 161 kWh/m² over the first two years of its existence. The simulation conducted under the LEED-Canada Program to demonstrate its optimized concept registered a simulated annual consumption of 136 kWh/m². Several factors can explain the difference between the simulation results and the real statistics (actual weather conditions, actual occupation rate, unaccounted-for loads...). However, it is important to keep tracking the building's energy consumption when in operation to ensure an optimal performance. In this sense, a simulation can help to determine a diagnosis of any problem, an evaluation of the impact due to a change in operations or the application of new energy efficiency measures.

Weather data
To compare the simulation with the real consumption data, the weather data over the analysis period must be used. Since no weather data was registered on the site, they were obtained by downloading Montreal weather data for the period directly from the following website: (Hydro-Québec, 2010)

Automated meter reading (AMR)
The building is equipped with an AMR that registers the building's overall electricity consumption every 15 minutes. This data gives the required information to understand the building's consumption and evaluate the accuracy of the simulation.

Figure 2 illustrates the daily profile classification for 2009 of AMR’s data using the SIMEB visualization tool. The calendar on the left of the figure displays the classification colour of each day of the year. On the right, each class is represented by a graph displaying the hourly profiles of the classified days. The curve in bold on each graph represents the median value of the profiles.

Class 1 shows constant week-end profiles throughout the year of close to 100 kW. Class 2 includes generally the summer weekdays and shows a gradual increase in consumption during the day, which reaches 150 kW. Class 6, on the other hand, shows weekdays during heating season, characterized by a consumption of approximately 100 kW in the morning when the building's activities start after the night setback. In addition, it should be noted that, in Class 5, there is a potential cycling problem at the beginning of the year. This problem was discussed with the building manager who confirmed that there had been a modification of the operation at this period.

The illustration of the classified daily profiles leads us to believe that the building is properly operated and that schedules are adhered to. The analysis of the real consumption with the classification tool was the first step toward understanding and conducting a simulation of the true performance of the building.
Building simulation

In this Case Study, three simulation levels were conducted with different calculation engines. SIMEB allows conducting building simulations very rapidly with little information. Detailed simulations can also be carried out if the user wishes a more in-depth analysis.

SIMPLIFIED SIMULATION USING DOE2.1 (Simp_DOE2)

A simplified simulation requires a different way to define the zones. Instead of dividing a building in thermal blocks, SIMEB requires that only the so-called functional zones of the building be identified. An internal algorithm creates the thermal blocks based on these functional zones and some characteristics (building envelope area, orientation, intrinsic perimeter zone depth,...). The algorithm is described in detail in (Bellemare et al., 2008).

Only 12 functional zones were necessary to describe the building in the SIMEB interface. In addition, several simplifications were performed at the HVAC level. For example, the radiant flooring was not taken into account and was simulated by hot water baseboards. The sand-based storage tank was also not considered. The outside air supplied by the fan coils was considered to be direct and not conditioned by the highly glassed-in atrium. SIMEB proposes a number of common choices as far as the systems, configurations and type of controls are concerned. However, some configurations are not available and require some assumptions in order to simulate the real operations of the building.

SIMPLIFIED SIMULATION USING ENERGYPLUS (Simp E+)

To conduct a simulation with EnergyPlus, the SIMEB building geometry wizard was used. This tool proposes predetermined thermal blocks by way of simplified shapes, as illustrated on Figure 3. Using this option, a model of the studied building was generated using 40 or so thermal blocks. The
same assumptions described above for the HVAC were used.

ADVANCED SIMULATION USING ENERGYPLUS (Detail_E+)
Finally, a comprehensive geometric model as shown in Figure 1 was drawn using Google Sketchup. The model was imported to SIMEB and a simulation was launched. In order to improve the simulation, the E+ input file was modified manually and directly by way of the SIMEB interface in order to include radiant heating and controls that were more adapted to the building's real operations.

Calibration
The three simulations were calibrated based on past electricity consumption. As far as the two E+ simulations are concerned, the calibration was conducted manually using a genetic algorithm (Daoud et al., 2011) on specific daily profiles. Many variables were adjusted: the infiltration levels, the output of the terminal HVAC systems, the thermal masses of the different zones, the plug loads fraction during non-occupied period, the insulation R-value and the amount of outside air. The calibration was conducted on 6 typical daily profiles (weekdays/week-end and winter/summer/mid-season) selected by way of the clustering method tool applied on AMR data.

The simplified simulation with DOE2.1 was automatically calibrated with an integrated SIMEB module. This module varies a number of parameters selected by the user to minimize any gaps between the building's real monthly consumption (energy and demand) and the simulated data. The amount of outside air intake, the plug loads and lighting power density were automatically modified by the tool.

Results
In Tables 1 and Figure 4, we have compared the real consumption data and the simulation data for 2009 on an annual and monthly basis. As shown, the simplified simulation with DOE2.1 underestimates the real consumption during the summer whereas the simplified simulation with E+ underestimates the consumption during the winter months.

<table>
<thead>
<tr>
<th></th>
<th>Year 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real</td>
<td>171.5 kWh/m²</td>
</tr>
<tr>
<td>Simp DOE2</td>
<td>158.5 kWh/m²</td>
</tr>
<tr>
<td>Simp E+</td>
<td>172.5 kWh/m²</td>
</tr>
<tr>
<td>Detail E+</td>
<td>177.5 kWh/m²</td>
</tr>
</tbody>
</table>

Table 1: Annual Consumption (kWh/m²)

Figure 5 shows the difference between the real profile and the simulated profiles during a winter week. The simplified simulation with DOE2.1 tends to underestimate the real profile when the building is vacant and to overestimate it when it is occupied. The detailed simulation with EnergyPlus (Detail_EP) is more in keeping with the real profile.

The sub-metering of the main consumption usages (lighting, heat pumps, hot water) is now underway to validate the different models used. Afterwards, a series of scenarios (thermal accumulation in the sand-based storage tank, optimizing controls, etc.) will be simulated.
Our study to date has demonstrated that the level of detail in our simulations depends upon the results that we expect. Many efforts must be taken into account to obtain a very accurate simulation; however, a simplified simulation can be very effective. SIMEB has the tools to provide the rapid or detailed simulation of an existing building and to compare the results with its metered data.

CONCLUSION
The development of SIMEB had in mind to push a market transformation toward the use of simulation tools in order to improve the design and retrofit of buildings. The different tools that have been integrated in SIMEB fill some needs requested by users and tend to facilitate the appropriation of simulation from new users. The presented Case Study has shown a typical application of SIMEB for improving the energy efficiency in buildings.

More outreach activities, such as development of learning lessons, training and development of internet community, are planned in order to achieve the potential goal of energy saving.

Further work on SIMEB tool will be oriented on existing buildings representing the biggest energy saving potential for next decade. Building energy simulation software available commercially do not put a lot of emphases on existing building aspects. New techniques of calibration based on AMR or sub-metering will be studied and eventually linked to SIMEB tools.

REFERENCES


Fournier, M., Lavigne, K. (2010); Daily load profile clustering: A tool for simulation calibration), Sixth IBPSA Canada Conference Winnipeg, Canada, May 19-20, 2010


