From the first sketch of your design, instantly simulate your project’s bioclimatic performance with the 3D simulation software ArchiWIZARD Bioclim

Audrey BASTONERO\textsuperscript{1}, Philippe ALAMY\textsuperscript{2}

\textsuperscript{1}HPC-SA, Montreal, Quebec
\textsuperscript{2}HPC-SA, Toulouse, France

Abstract
As simulation tools for building efficiency are now requested in the design practice, the French energy simulation software “ArchiWIZARD” has been adapted to the Canadian use, leading to the new “ArchiWIZARD Bioclim” software. It is a new collaborative and decision-support 3D solution, which help designing efficient buildings at the earliest phase of a project. This software is to be used to estimate and visualize the impact of any design choice from the CAD in terms of energy efficiency. User-friendly 3D interface is to enable changing configurations of the building envelope, occupancy scenarios, urban environment, solar energy, and instant feedback on thermal loses, energy needs, day lighting. The simulation core is based on Raytracing technologies and thermal engines.

1 Introduction
Reducing the carbon footprint of buildings has become a worldwide crucial issue in the Construction field, leading Canadian energy standards and Green Building Rating Systems to increase energy performance requirements and to incorporate Green Buildings’ concepts in the building design. As a consequence, the use of building performance simulation software has been promoted in the design practice. For instance, in the LEED Canada New Construction & Core and Shell 2009 rating system, (Canada Green Building Council, 2010, sec Energy and Atmosphere, credit 1 Optimize Energy Performance), the option that allows to gain the most points is the one requiring building energy simulation tool. Moreover, there is an approved list of software that the Canada Green Building Council recommends (2013).

Using simulation software is relevant in designing Green Buildings because it allows to have projected qualitative and quantitative results on how the building is efficient. They can be used either to help making decisions (qualitative comparison of the impact of several technical scenarios, designers choosing the less impacting one), or to confirm and validate choices.

Though there is a condition to optimize the green building design workflow: it is for the enlarged design team to collaborate from the first steps. Indeed, exchanges between the AEC team members (architects, engineers, builders) are time consuming. Building Information Modeling (BIM) is a process and a technology that enables an integrated design, which has been developed to facilitate exchange amongst a design team.

It is in this context that ArchiWIZARD Bioclim (written AW Bioclim subsequently in this report) has been developed: linked to the main CAD solutions through dedicated plugins, it has been adapted from the French master version to be used by the most enlarged team. Major adaptations concern BIM configurations, interface, data inputs (weather data, CAD
plugins). Thermal calculation comes from international standards and HPC-SA Raytracing innovation.

This collaborative solution is to guide building designers in a sustainable design intent, from the earliest stages of the design process, in order to optimize the Green Building Design workflow.

2 Methodology

This section will deal with the green building key features available in AW BioClim.

Importing a 3D model in a bioclimatic environment

There are two ways of importing a CAD model to instant simulate its bioclimatic performance: the dynamic synchronization mode, and the “classic” import (in other words, the File>Open function for standard formats). Because the second option is quite obvious, we will focus our explanations on the first dynamic mode.

The dynamic synchronization allows the user, while working on his CAD software (thanks to a dedicated CAD plugin), to import the 3D model with few clicks. Indeed, an AW button / add-In is available in the menu bar of the 3D software, as shown on the Figure 1.

![ArchiWIZARD icons for synchronisation with Revit and SketchUp](image)

Figure 1: ArchiWIZARD icons for synchronisation with Revit and SketchUp

Once a first import has been done, any new synchronization with the same model will update geometric changes, keeping any configuration data set up made through AW BioClim.

During the import process (either of the two options mentioned above), the geometry of the CAD model is analyzed, in other words the set of triangles that form the walls, floors, roofs, windows…etc, and the spatial relations between them. This assumption enables AW BioClim to import a model from almost any CAD software. To perform the import, some information such as textures in SketchUp, and elements’ categories in Revit, are recognized.

Note: There are 3 selection modes in the 3D simulation model to check whether it has been well imported, as shown on Figure 2.

![Object mode](image) ![Surface mode](image) ![Volume mode](image)

Figure 2: 3 selection modes to check the quality of the CAD import
As the surrounding environment (buildings, vegetation, etc…) has a considerable impact on a building’s bioclimatic performance (because of solar shadings/masks), it is essential to import it properly and to position it correctly. Using the drag&drop technology, the project environment can be quickly imported in the AW Bioclim’s interface and well positioned.

ArchiWIZARD Bioclim is compatible to the main 3D and BIM software, as shown on the Table 1. Thus it can be used for almost any project.

**Table 1: CAD compatibility with ArchiWIZARD Bioclim**

<table>
<thead>
<tr>
<th>Dedicated CAD Plugins for:</th>
<th>Supported formats for classic import and environment drag &amp; drop:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revit</td>
<td>.dwg</td>
</tr>
<tr>
<td>SketchUp</td>
<td>.skp</td>
</tr>
<tr>
<td>ARCHICAD</td>
<td>.obj</td>
</tr>
<tr>
<td>Allplan</td>
<td></td>
</tr>
<tr>
<td>Vectorworks</td>
<td></td>
</tr>
<tr>
<td>Envisioneer</td>
<td></td>
</tr>
</tbody>
</table>

**Assigning bioclimatic data to a model**

Once a 3D model is imported into AW Bioclim, parameters can be configured in one click for the whole project (building + environment) as for any thermal zone of the building. A thermal zone can be a single room, or a group of rooms.

Parameters that can be set are:
- Geographic location (choice of a weather file; supported files formats: .epw and .tmy2)
- Project’s orientation (with respect to the cardinal directions)
- Composition for walls/floors/roofs (detail of the materials and layers used)
- Composition for windows (glass, frame, opaque infill, protections)
- Building type use (temperature setpoints, forced ventilation flow, air leakage, internal contributions (due to occupants and equipments), occupancy schedule, heating/cooling schedule, ventilation use schedule, artificial lighting use schedule…). Figure 3 shows the parameters that must be sent according to the ventilation use.

![Figure 3: Zone configurator (Ventilation tab active)](image-url)
For the first import of a CAD model, it is possible to choose a standard configuration based on the requirements of the Model National Energy Code for Buildings 1997 (Canadian Commission on Building and Fire Codes, 1999), or to use an AW Bioclim customized configuration (including all the envelope description and the building use).

At the early stages of the design process, data set-up must be quick, so designers do not lose time before getting the first feedback. That is why the use of drag & drop technology is available for data entry of parametric objects, directly from the AW Bioclim libraries or from customized libraries and configurations (saved compositions of walls, windows, scenarios, materials, glazing) directly set up through the interface.

In order to simulate the addition of a window or the enlargement of an existing one, without modelling it in the CAD software and pass through synchronization, a parametric window from the software library can be used. Actually Figure 4 illustrates how a simulation window has been positioned directly on the AW model by drag & drop. Dimensions and physical parameters can be modified, until the best combination is found. The right object is then defined to be selected in the CAD.

Other parametric objects are available, such as sun protections / brises-soleil.

---

**Optimizing daylighting and solar gains**

One of the most important issues in green building design is to try benefitting the most from solar effects. That means maximizing the use of natural daylight (which reduces the artificial lighting needs), and optimizing the solar gains (in order to reduce the heating / cooling energy needs). In a bioclimatic design intent, these calculations are essential.

Calculations of daylighting and solar gains are done in AW Bioclim using raytracing technology combined with weather data. It is a dynamic simulation method (less than hourly steps).

In order to obtain accurate results after a reasonable period of time, the probabilistic Monte Carlo Method is used to calculate the indirect and diffuse components. It consists in launching a random sampling of rays, and minimizing the inevitable error using statistic methods (see our online paper: http://www.hpc-sa.com/fr/publications).

This technology allows to have both daylighting (luminance) and solar radiation (irradiance) results; anywhere outside the building and inside it.

**Minimizing the thermal energy “needs”**
Energy needs is the amount of energy that should be available to satisfy occupants’ demand (according to building use). Calculation of these energy needs takes into account the performance of the building, and the on-site production of energy (if renewable energy is to be utilised, such as solar energy). Actually, the aim in designing the less impacting building is linked to reducing its energy needs.

During a predesign charrette, it is difficult to have a clear idea of the building’s performance without heavy calculation. That is why AW Bioclim is been developed: the thermal results are based on a hybrid thermal method, based on common physics considerations and European standard codes (http://www.archiwizard.fr/fr/technologie/les-methodes) allowing real time calculation. Indicators are directly displayed in the 3D interface, so building designers can visualize its building’s energy performance. There are also graphs, diagrams, and histograms results as well.

All these results are updated in real-time, which means after each data configuration modification and each geometry change in the 3D software (updated after a synchronization).

Amongst the relevant indicators, we can list these ones:

- The projected energy needs of the building. Five are calculated, for each of the crucial energy use: Heating, Cooling, Artificial Lighting, Hot Water, and Ventilation.
- Solar renewable energy potential, for thermal and photovoltaic solar panels. Indeed, as placing a solar panel on the 3D model, its produced energy is directly available to the building designers.

Every graphs, histograms, diagrams, charts are also updated in real-time, which helps the user visualize the impact of any change (configuration, geometry) on the building’s performance.

- The energy balance of the building is a histogram illustrating, for each month of the year, the heat input (provision of heating, solar contribution…) in the upper area; versus the heat loss (cold supply) in the lower area.
- A diagram illustrating the thermal loss distribution. For each type of element (for example openings or roof type), we calculate the percentage of loss in relation to the total building losses.

When more accurate results are needed, further in the project, such as thermal calculation and comfort evaluation done for each zone or each room, the Dynamic Simulation Method (EnergyPlus thermal engine) can be used. The EnergyPlus v8.1 engine is embedded in AW Bioclim (incorporated in the installer). Every relevant data set up and inputs are made in AW Bioclim from the CAD, (see before), converted into EnergyPlus inputs and simulation is launched from the AW Bioclim interface. When more detailed calculation is needed, engineers can save the EnergyPlus input configuration in an .idf file format they can modify and reuse directly.

Quickly interpreting the building’s bioclimatic performance with relevant indicators

Some of these indicators are displayed in the software interface, such as:

- Green buildings indicators, such as the Glazed Area Ratios depending on the Orientation (South, East, West, and North). For each orientation, this ratio is defined by the glazed area (in m²) in this orientation, divided by the total glazed area (in m²).
- The thermal comfort rate, which is the percentage of occupation time when the temperature exceeds the discomfort temperature. The presence of occupants is defined by the scenario of internal gains in the zone.
- The lighting comfort, which is the percentage of time when the lighting setpoint (minimum lux level) is achieved with daylighting in addition to artificial lighting, compared to the period when it is required (lighting use scenario).

These values help building designers identifying where to improve their design: for example, if the lighting comfort level is too low, it suggests that natural light level is not high enough. So efforts must be put to increase daylighting inside the buildings (increase the openings’ surface, use windows with a higher transmission luminous coefficient…).

3 Results

*Importing a 3D sketch in a bioclimatic environment*

Since it is mainly the geometry which is analyzed, any kind of building can be imported. Indeed, the Revit model represented in the Figure 5, illustrating the “Complexe le Gaspé” project led by the Architectural firm “Smith Vigeant Architectes”, is a 1 million ft² project, an existing building retrofit, and for a tertiary use. Whereas the SketchUp model is a 850 m² project, new construction design, for a mixed tertiary and residential use. The Figure 5 actually illustrates the AW Bioclim representation of two 3D models after synchronizing them (their respective environments have been positioned).

![5a: 3D model in Revit 2013](image)

![5b: Revit model imported into AW Bioclim, with the environment (dragged & dropped)](image)

![5c: 3D model in Google SketchUp v8](image)

![5d: SketchUp model imported into AW Bioclim, the its environment (dragged&dropped)](image)

Figure 5: Illustrations of 3D models in CAD software (Revit, and SketchUp) and their representations in ArchiWIZARD Bioclim

*Optimizing daylighting and solar gains*

Solar radiation results can be available all over the 3D model, to visualize the potentially overheated surfaces, the potential heat islands, and the appropriate location to install solar panels. What is calculated is the amount of energy brought by the sun (in kWh/m²) for a cer-
tain period of time. The impact of the environment is taken into account to have the most realistic predictable results.

Time periods of calculations can be set according to the designers’ interest: over the whole year, by season (hot season versus cold season); for a particular day… For the project illustrated on Figure 6, which takes place in Antarctica, the architects (“Smith Vigeant Architectes”) were interested in localizing the potential sets for solar panels, during the “hot” season and the “cold” season. The walkway appeared to be a possible spot they did not spontaneously thought of.

Figure 6: Solar radiation over a 3D project located in the Antarctica (South Pole)

After identifying the overexposed facades, designers can focus on an overexposed window to dimension a solar protection in order to optimize the solar gains through it. The aim being to maximize solar input during winter, in order to reduce the heating energy need; and to minimize solar gains in summer to prevent overheating inside the building, which helps reducing the energy need required to cool the building.

Using a solar receiver, “dragged & dropped” from the AW Bioclim library, building designers can visualize the quality of solar reception on this specific receiver. On the graph shown in Figure 7, it is indicated whether the reception is direct (in red) or indirect (in blue). This graph is updated in real time, depending on the solar protection parameters that designers can modify. Once results are optimized on the graph, it means the solar protection is well dimensioned. Designers can then model the solar protection in the CAD software, using the parameters he found in AW Bioclim.

Figure 7: Optimization of the solar gains through a window
Regarding the daylighting analysis, it is possible to put a “light map” which is actually a daylighting sensor, inside the building to visualize the amount of daylighting directly on the 3D interface. The height of the light map is customizable.

Two quantitative results are available: luminance (in lux) and Daylight Factor (in %). The luminance values depend on the day and hour (weather files data being used), whereas the Daylight Factor does not depend on the geographical location (climate) or timing (date), since it is calculated with a specific sky that characterizes the building regardless of the location. The daylight factor is calculated using the formula below (Baker, N. and Steemers, K, cited in Kensek Karen and Jae Yong Suk, 2011)

1) \[ DF = 100 \times \frac{Ein}{Eext} \]

Where Ein: indoor luminance level and Eext: outdoor luminance level.

A comparison of the luminance results versus the Daylight Factor results are available on Figure 8 for the same project.

For a quality analysis of the daylighting reception, on a localized surface (such as a screen, or a desk), it is possible to use a “light sensor” to predict the critical moments of glare (See Figure 9).

Figure 8: Daylighting levels visualizations : iluminance versus daylight factors results
Minimizing the thermal energy “needs”

In the case study of the Figure 10, the “Complexe le Gaspé” project, the architects wanted to have a quantitative impact of the refurbishment of walls on the building’s performance. They were looking for arguments to convince the building owner on the importance of refurbishing the exterior walls. AW Bioclim was used to simulate the existing building’s performance (with the existing wall composition), focusing on its projected heating needs. Then, it was used to simulate the building’s performance after refurbishment, to determine the predicted heating needs of the refurbished building. Results show that the refurbishment will allow to divide by 3 the energy need for heating use (34kWh/m² per year after the refurbishment, 94kWh/m² per year before). This argument was sufficient to convince the building owner.

In the other case study, the Antarctica project shown in Figure 11, AW Bioclim was used to help the architect choosing between two high-quality glazings. A building’s performance simulation was launched with each glazing. As a conclusion, the most performing (most insulating) window was not selected because it did not help reducing that significantly the building’s thermal performance (the heating need has only been decreased by 4%), which was not enough to compensate these windows cost. It seemed not cost effective to use the most performing windows, so the architects chose the least (and yet) performing glazing.
Ug = 0.84 W/m² K

Ug = 0.47 W/m² K

**Figure 11: Comparison of the building’s performance using 2 performing glazings**

In a bioclimatic approach, it could be interesting to use solar panels to cover the domestic hot water energy need (solar thermal panels), or to produce onsite electricity (photovoltaic).

In AW Bioclim, it is possible to set solar panel(s) directly on the 3D model and analyze the projected energy produced by them. AW Bioclim solar panels are parametric objects, which means their parameters can be modified by users.

*Figure 12 below:* the single thermal solar panel would cover 15% of the hot water energy needs of this project.
Figure 12: Thermal solar panels projected coverage

Fast interpretation of building’s efficiency with relevant indicators

The lighting autonomy is a really relevant indicator to know if the natural lighting is sufficient on the whole building, and even in each room.

13a: Before adding a new window

13b: After adding a new window in SketchUp

Figure 13: Updates from CAD model make change using the synchronization
On the Figure 13, the addition of a single window (modeled in the 3D software and then imported by synchronization), updated the results: the lighting autonomy of the specific room has increased from 6 to 70%; and the lighting autonomy for the whole building has increased from 35 to 36%.

4 Discussion

CAD import of models (from the first version of the design to the ultimate design)
The dynamic link between the 3D software and AW Bioclim is a one-way process: from the CAD software to AW Bioclim, not the way around. Designers, architects don’t want their whole design to be automatically modified from a simulation tool focused on energy performance.

It is true that the building information are not fully imported in AW Bioclim with the actual import process, because AW Bioclim does not read the composition of walls/roofs/windows…etc set in the CAD software. Only the geometric category is detected. However, this restriction is motivated by technical reasons: each CAD uses its native format (such as .rvt for REVIT) and libraries for the BIM objects description mode. Interoperability is not mature today (IFC and gbXML are not yet passing our evaluation criteria for the range of simulations ArchiWIZARD Bioclim offers).

Our motivation as an editor was to create a unique ArchiWIZARD BIM with the best geometrical import mode, able to run with any CAD with the less errors in terms of BIM interpretation.

Quick results, updated in real time, yet still reliable
In comparison to other building performance simulation software, data set up in AW Bioclim is quite intuitive (with the drag & drop technology for instance) and quick, such as results. Whereas Radiance, the UNIX based software Radiance, using a command-based interface, requires some computing skills to configure a simulation. Indeed, RADSITE (2013) states on the Radiance-online website “Generally, the package is well-suited to programmers and people with a high degree of computer proficiency”.

Even if the results are quickly calculated in AW Bioclim, it does not mean that they are not reliable. As it is shown on Figure 14, regarding the daylighting results.

Figure 14: Exterior illuminance comparison of ArchiWIZARD Bioclim results and other referenced daylighting software
To obtain the Figure 14, we used several software (3ds Max Design, Radiance export using Ecotect Analysis, and ArchiWIZARD Bioclim) and we measured the exterior illuminance in Phoenix, USA, for relevant days and hours (21\textsuperscript{st} of June, December (summer and winter solstices), March and September (vernal and autumnal equinoxes); for each day at 6am/9am/12am/3pm/6pm). This Figure shows that AW Bioclim results are similar to these well-known software results.

5 Conclusion

Building bioclimatic performance can be simulated at the first stage of the project using the ArchiWIZARD Bioclim software. Indeed, the main decision-making criteria are available to help building designers maximizing the daylighting and the energy input (such as solar energy), while minimizing the building thermal needs.

To optimize the design workflow, ArchiWIZARD Bioclim allows a fast and synchronized CAD import combined with real-time updated results. The strength of this building performance simulation software is that designers can evaluate the impact of any change of a configuration, or a design option, keeping their design process as it is. So they can choose the best options to design greener buildings as soon as possible. Consequently, this software helps minimizing the design risk and optimizing the bioclimatic performance from predesign charrette until existing buildings rethinking: time and money are saved.

Moreover, it is a collaborative decision-support tool to be used by both architects and engineers, at the same time, in the same team also, thanks to its several simulation engines (for daylighting, solar radiation, thermal analysis…) and the several expertise levels in data setting (from the intuitive results, to the .idf file configuration).

Real-time updated results may not be as accurate as other specialized software, but they are sufficiently reliable and indicative to guide designers. If they want to have more accurate results before making a final decision, the EnergyPlus engine may be used.

The ability of this software to be used on existing buildings to simulate their refurbishment (interior spatial reorganization, or materials compositions) is the strength of this solution that can help removing barriers from application of building performance simulation in the design practice.

6 Nomenclature

Units
m\(^2\): square meter; ft\(^2\): square feet; m: meter; W: Watt; K: Kelvin; kWh: kilowatt hour

Files formats
.dwg: drawing, AutoCAD format; .skp: SketchUp format; .obj: Object format; .epw: EnergyPlus weather file format; .tmy2: Meteonorm weather file format

7 References


Karen Kensek and Jae Yong Suk, *Daylight Factor (overcast sky) versus Daylight Availability (clear sky) in Computer-based Daylighting Simulations*, School of Architecture, University of Southern California, viewed 6 August 2013, http://www.sersc.org/journals/CSABE/vol1/2.pdf


**RADSITE 2013**, RADSITE radiance-online.org, viewed 6 September 2013, http://www.radiance-online.org/about/detailed-description.html