EDG 90 RM • August 2017 (Edited 03.08.2018)
environmentdesignguide.com.au
Reviewed and approved for currency in August 2018

ISSN 2207 - 466X

Sustainability and Building Information Modelling (BIM)

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Cover image: Fleurieu Aquatic Centre, South Australia, by dwp and Hames Sharley. Sustainability tools within BIM drove a successful environmental performance outcome (Photo: Emma Cross Photographer).

Abstract

This note introduces readers to some of the current environmental analysis tools available within Building Information Modelling (BIM) software packages. It highlights some of the fundamentals that underpin BIM and sustainability and then takes readers through some basic principles around when and why to undertake environmental analysis and how to develop the relevant capabilities within design practices, regardless of their size. The note explores several analyses available to users within the different software packages, detailing what each analysis is, how it works, why it's important and other relevant information, concluding with an exploration of some non-BIM tools and considerations beyond BIM that designers should be mindful of when creating truly sustainable designs.

Introduction

Though the concept of Building Information Modelling (BIM) has been in existence in one shape or form since the 1970's (Eastman et al, 2008), its uptake in Australia has dramatically increased in the past 5 - 10 years. This guide is written for both the novice and expert in *BIM* and similarly in sustainability, so that it is equally accessible to as many design professionals as possible. It is hoped this guide will help demystify some of the perceived barriers to sustainability and enable more environmentally responsive design solutions.

This guide is structured in three parts:

- Part 1: Background - background information on both BIM and sustainability and the opportunities that currently exist for sustainable design
- Part 2: Revit analysis tools - a technical exploration of the current environmental analysis tools available in *Revit*
- Part 3: Alternative tools - a look at other software tools that are available to designers that enable sustainable design.

Note: Due to its overwhelming market dominance, Revit® software will be the primary BIM package explored in this guide. Opportunities within *ARCHICAD*, *Rhino/Grasshopper* and *SketchUp* plugins are also discussed, though not to the same extent.

This note is focused on BIM and the opportunities for sustainable design it, and associated software, provide. It should be noted that BIM does not fully replace conducting traditional environmental analysis and investigation prior to modelling. Accordingly BIM results and analysis should be checked against traditional methods, and vice versa, to ensure maximum accuracy and highest design value.

Note: terms denoted in italics are defined in the Glossary.

Part 1: Background

1.1 Defining sustainability

When discussing sustainable development the most widely held definition used is that identified by the Brundtland Commission in the late 1980's: 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland Commission, 1987). Furthermore, designs can only be deemed truly sustainable when they are equally socially, economically and environmentally sustainable (Figure 1).

The emergence of BIM presents a great opportunity for architects and designers to engage in sustainable design through environmental analysis tools, ranging from climate analysis to life cycle analysis, on a level not previously possible through traditional design and documentation processes.

1.2 Defining BIM

BIM is essentially data management, whereby a series of inputs can be visualised on screen in multiple ways including 2D and 3D drawings, numerical data sets, etc. It has become extremely popular as a documentation tool, replacing traditional 2D drawing packages such as *AutoCAD*. This is because it can greatly reduce the amount of time needed to produce drawing sets and can also reduce documentation coordination issues. This occurs through data being entered either numerically and/or visually into the program, which assembles it as one completed 3D model, as opposed to a series of generally unrelated 2D drawings. 2D views can be extracted from the 3D model and if one view is altered then the model automatically updates the other views.

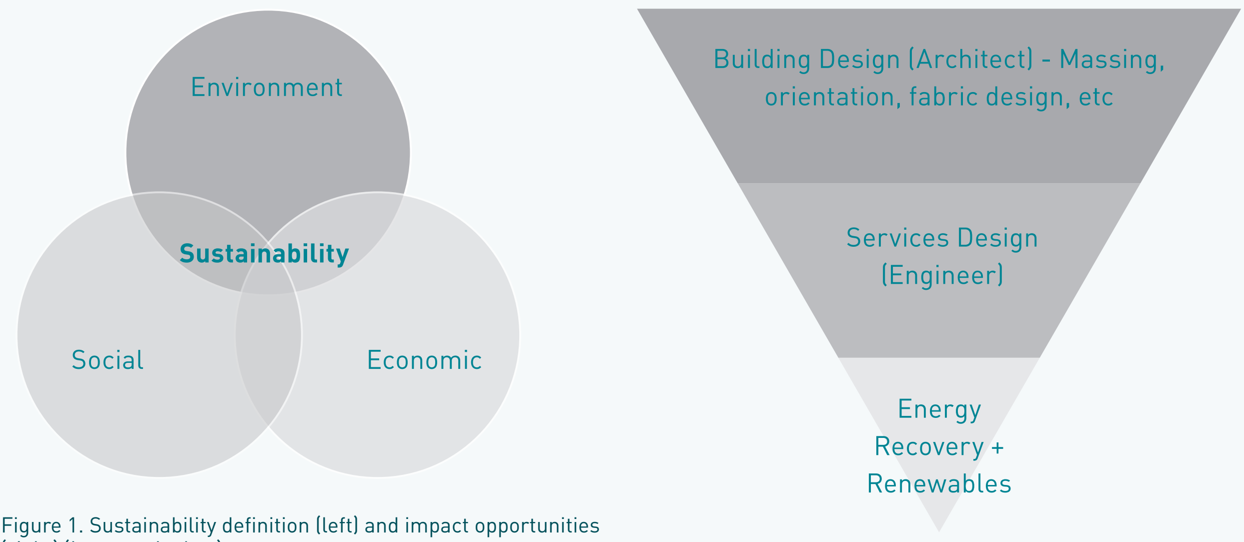


Figure 1. Sustainability definition (left) and impact opportunities (right) (Images: Author)

The difference in the processes can be visualised like this:

If 2D software packages were represented by traditional hand drawings, whereby every drawing required was drawn, coordinated and altered independently, then BIM would be like building a 3D model and taking photographs of that model and then slicing through it to reveal plans and sections as needed. If the 3D model is altered then the photographs would automatically reflect the updates regardless of whether they were plans, sections, 3D's, etc.

A BIM model can have a long life, not only through the design, documentation and construction of a building, but afterwards, as facility management data for complex buildings and reused as base information should a building undergo an upgrade, addition or demolition.

1.3 Opportunities for sustainability within BIM

When exploring opportunities within BIM to improve the sustainability of buildings, designers are primarily focused on what can be achieved during the design process. This is because BIM allows iterative testing of alternative design strategies from initial massing and orientation right through to building envelope design to minimise operational energy requirements and maximise occupant comfort. These strategies can be further refined through analysing building relationships with wind, daylight and solar radiation to identify appropriate opening locations and optimise building fabric strategies, etc. In deciding these strategies early in the design process and validating them through the modelling, these strategies may have a greater chance of being implemented in construction, as their inclusion will be integral to realising the design.

It is also critical that the designer thoroughly considers sustainability in the early stages of design, as some of the decisions made early on (orientation, massing, building fabric, etc.) will be fundamental in determining the operational energy requirements of a building. By the time engineers are normally appointed on projects these decisions can be locked in and opportunities for sustainability reduced. Ultimately, mechanical design can only react to the energy requirements created by the building geometry and user needs, while renewable energy can normally only help offset some of these needs thereafter.

1.4 Undertaking sustainable design with BIM

1.4.1 Timing: When to do it

One of the greatest challenges in sustainable design is ensuring that it is considered early enough in the design process. Sustainability should be a fundamental of any concept, or at least considered as an enabler of the concept. The opportunity to integrate sustainability decreases as a project progresses, while the cost for its implementation increases (Figure 2). When sustainability is considered a fundamental of design there is less likelihood for it to be 'value managed' out.

Environmental analysis of concepts should occur iteratively from the start and the results used to inform design evolution. As the design evolves the sophistication of the analysis can increase so that when it comes to collaborating with other consultants it is already 'on the right track' and the situation where a design needs to be 'made sustainable' later is avoided. Ultimately, the ability of the designer to minimise energy requirements and maximise occupant comfort through passive design early on is essential in realising a sustainable design solution.

It should be noted that some debate exists in practice on how early to introduce BIM in the design process. Alternative tools such as Rhino/Grasshopper (refer Section 3.6) allow the flexible testing of multiple options in the early design phase.

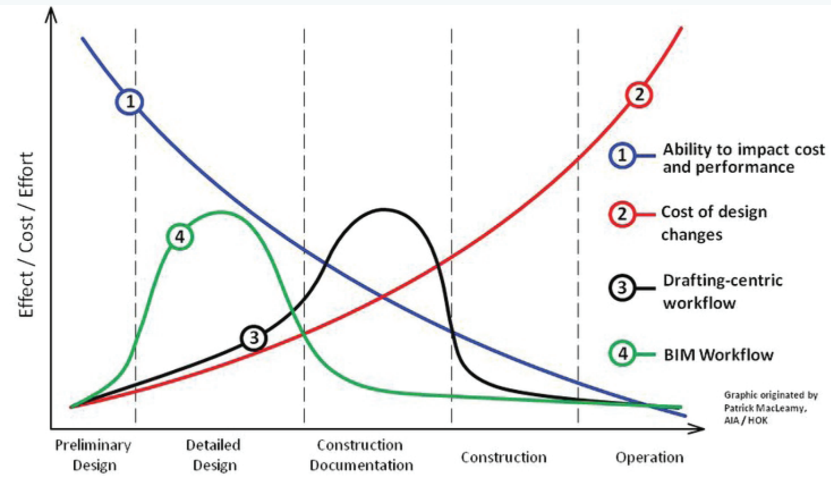


Figure 2. Opportunity (effort) vs time (progress) (Source: MacLeamy, P. HOK, 2009)

1.4.2 Organisation and training: What to know

Small practice versus large practice

As different sized architectural practices have varying needs and implementation strategies for BIM, environmental design integration should be tailored to meet the needs of the organisation. For smaller teams, there exists the proximity and intimacy for all design staff to undertake environmental analysis in BIM throughout the life of a project. For larger practices, it will require greater support from leadership to be embedded on multiple projects and may require a 'champion' to coach project teams on the requisite analysis tools and results.

Training: Autodesk® Building Performance Analysis Certificate

Comprehensive educational support is available from Autodesk in the form of the Building Performance Analysis Certificate (BPAC) Program (figure 3). This course not only shows participants how to utilise the tools and undertake analyses within Revit, but also takes them through the fundamentals of environmental design so they can understand what the results mean and utilise their findings to improve their designs.

Further information: https://sustainabilityworkshop.autodesk.com/bpac.

Information supporting sustainable design from Autodesk: https://sustainabilityworkshop.autodesk.com/building-design

1.4.3 Data: What goes in and what comes out

The golden rule in environmental analysis within BIM is that results will only be as good as the data used. When modelling, it is important to model and locate your building as accurately as possible as this will provide you with the most accurate results. Data sets typically used within BIM include:

Geometric data:

This is effectively the model that you can create and will typically include walls roofs, doors, windows, stairs, etc. of not only your building but of any other built form context you've modelled. 'Conceptual massing' is also deemed 'geometry'.

Climate data:

This is the climate data set identified by Revit based on a project's location and is used in multiple types of analyses (this is explained in greater detail under 2.1 Climate analysis).

Materials data:

This is primarily the thermal conductivity and reflectivity values for the model's materials and is used in undertaking energy and daylighting analyses. In conceptual analysis Revit limits the ability of users to tailor and edit these values, however in 'element mode' (more detailed analysis) each material can be edited individually.

Building and usage profiles:

This data is preloaded within Revit and allows users to select the likely building use and operations pattern that would be expected for different building types, e.g. a school, hospital, etc. Understanding occupant and usage patterns is important as the difference in energy used by a building that operates 24/7 compared to one that operates 9am-5pm can be substantial.

Outputs:

Revit will produce outputs primarily in two ways. Firstly, as a report detailing likely energy consumption and climatic data via charts and graphs and secondly as data represented in 3D on screen which can then be captured as images for inclusion in reports etc. Revit also allows data to be exported as a *gbXML* file for further analysis online and/or by other more powerful software including *IES, Design Builder*, etc.

Figure 3. Building Performance Analysis Certificate (Source: Autodesk, Inc. 2017, Copyright © Autodesk, Inc.)

Part 2: Revit analysis tools

2.1 Climate analysis

What is it:

Climate is the first thing that architects and engineers should consider when designing a building. It is essentially an analysis of historical weather records for a particular area (normally over a 20 - 30 year period) which is then averaged out to give a typical set of values for a year. It will normally consist of temperature, humidity, wind and daylight data.

Why is it important:

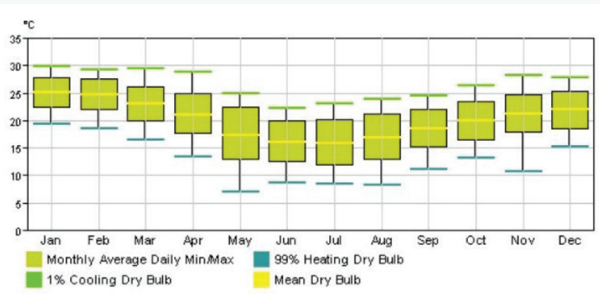
It is important to understand the climate of a site as it will dictate what passive design strategies are most suitable for the site. Buildings are often a reaction to their environment, both built and natural, and therefore the internal conditions will be reflective of the building's interaction with its climate. When a design is optimised climatically then it will be more comfortable naturally and require less energy for heating, cooling, (de) humidification, lighting, etc.

How does it work:

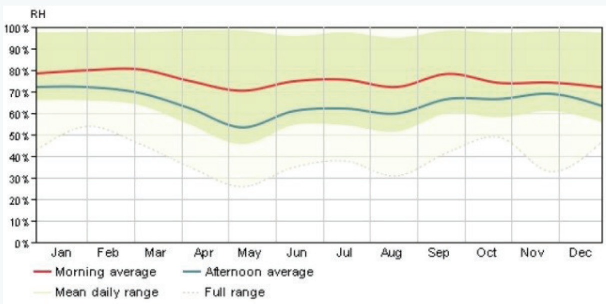
Running a climatic analysis within Revit is straight forward. Firstly, identify the site for your project via the 'manage' tab and then create some built form on the site – either a conceptual mass or by using typical wall, roof or floor elements. Once you run an energy analysis based on the newly created object, the climate data will be automatically generated for consideration (Figure 4).

What to note:

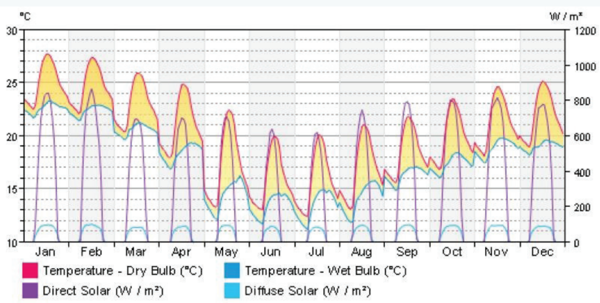
While the climatic data presented by Revit is helpful it is worth noting that it is primarily made up of virtual weather stations from simulations run in 2004 and 2006 (at the time of writing), as well as physical weather station data (TMY2) and historical data (WRF). This is so that every possible site on the planet, when modelled, can have climate data available. This makes it slightly less reliable (and less comprehensive) when compared with data from Climate Consultant (described under Alternative tools). It is possible that Revit's climate data may not be consistent with Bureau of Meteorology (BOM) data, as BOM is particular to Australia.



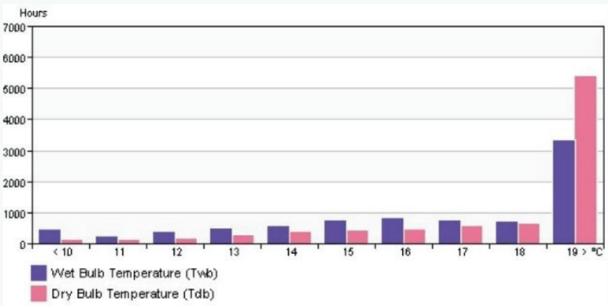
Monthly design data



Humidity



Diurnal weather averages



Annual temperature bins

Figure 4. Revit climate data, Revit® (Source: Author, 2017, 'Autodesk screen shots reprinted courtesy of Autodesk, Inc.')

2.2 Shadow studies

What is it:

A tool which allows designers to study the movement and position of the sun through the seasons and time of day and utilise building massing and orientation to optimise the building's solar access. It graphically represents the shadows cast by modelled masses in both 3D and 2D images so that shadows cast on, or by, a proposed design can be easily visualised and assessed.

Why is it important:

Optimising the orientation and massing of a building in relationship to its surroundings is one of the most important steps in achieving good passive design outcomes and minimising dependency on mechanical heating and cooling and artificial light. The shadow studies tool allows designers to identify exactly when and where light will fall on openings. In general, by shading openings in summer to protect from excessive heat gain and exposing them to sunlight in winter to increase the solar heat gain, the amount of energy a building needs to heat and cool its interior can be reduced.

How does it work:

Similar to setting up the climate analysis you must first locate your project geographically so that Revit will know what sun path data to use. The geometry of the project must then be modelled, including any proposed windows and skylights, as well as any surrounding buildings or known geometry. Once this is complete, and sun path and shadow settings have been turned on, the date and time settings of the shadow study can be changed to map sun movements across varying time periods. This process can be used iteratively to optimise the orientation, massing and shading strategies of a proposal.

What to note:

It's important to note that this analysis is different to that of the solar radiation analyses described under 2.3 Solar radiation. While this study can be used to ascertain when and where sunlight will strike a building, and therefore experience *direct solar heat gains*, it does not help ascertain overall heat gains. It is a very useful tool in supporting town planning submissions and conditions should normally be modelled on the spring/autumn equinoxes at 9am, 12pm and 3pm. For understanding extremes, model the same times for the winter and summer solstices. It should also be noted that section boxes and hidden geometry influences the shadows.

2.3 Solar radiation

What is it:

Solar radiation studies within Revit calculate the likely solar heat gains a project will experience due to its geometry and climatic conditions. The climatic data described previously also includes solar radiation values for each location which, when modelled, can be visualised in 3D to identify the level of heat gain individual surfaces will receive. This can be broken down into incidental and cumulative values for different times of the year to better understand when and where desirable and not so desirable gains are.

Why is it important:

This is an extremely important and useful tool used to optimise a building's orientation and massing, as well as opening size and location of shading strategies to minimise cooling requirements in summer and heating requirements in winter. It is a powerful visualisation tool as the 3D representation of the modelled analysis easily illustrates affected surfaces as well as successful and unsuccessful shading strategies.

How does it work:

This analysis tool uses the climatic data described previously and combines it with the geometric data of the project and surrounding modelled built form (if any). Surfaces for analysis can be selected independently or within a whole model. Analyses can be undertaken on conceptual masses and building elements and components alike. Strategies may be validated by running a 'conceptual energy analysis' (described under 2.6 Conceptual energy analysis) to identify if the proposed strategies have reduced heating and cooling requirements for the project.

What to note:

This tool is not a standard inclusion within pre Revit 2016 and can no longer be downloaded separately. For Revit 2016 and later it is a standard inclusion as part of the Insight 360 download (Refer section 2.7 Green Building Studio / Insight 360). It can take considerable time for Revit to conduct a solar radiation analysis, therefore minimising geometry complexity (or amount of) to be analysed can substantially reduce the time required to conduct the analysis.

2.4 Computational fluid dynamics (CFD) – Flow Design

What is it:

CFD modelling is the digital simulation of air (or sometimes water) through and around objects. It can be used to identify where hot and cold air might travel in and around buildings or what parts of buildings may be over-exposed to, and require protection from, seasonal winds. It can also be used to identify passive cooling strategies for proposals. At present, Revit/Autodesk products support this with two paid software products: Flow Design and Autodesk CFD. Flow Design is a cheaper basic CFD software that can assess air movement through and around buildings, while Autodesk CFD is a more expensive and powerful package that can study thermal air movements and is very useful in modelling thermal comfort. Also refer 'Butterfly' under Section 3.6 Revit and Dynamo/Rhino and Grasshopper plugins.

Why is it important:

Understanding air flow in and around buildings is important for primarily two reasons. Firstly, optimising passive air flow through buildings can help reduce air conditioning and cooling requirements, greatly reducing energy needs by the optimal location and sizing of windows to support passive ventilation. Secondly, in modelling the movement of air around buildings we can mitigate some of the effects of wind tunnelling, whereby wind is accelerated down streets due to the makeup of the built form. It can also identify optimal areas to locate entries so that when people leave the building they are not confronted by strong gusts. This is particularly important when designing for vulnerable groups such as the elderly or those with mobility issues.

How does it work:

Flow Design can act as a standalone product or as a plugin within Revit, while Autodesk CFD is a standalone product that requires a greater level of skill and knowledge to operate. Individual wind scenarios (direction, velocity, period etc.) can be identified for exploration, having been identified from the climatic data discussed previously, and then programmed into Flow Design for analysis (note: built form, including geometry must be modelled prior to analysis). The software will then show air moving around the built form 'live' in video format. Varying speeds will be depicted in different colours identifying areas of acceleration, deceleration and greatest velocity.

What to note:

Flow Design represents the analysis in both 3D and 2D, making it easier to understand how air could move through a building via openings, etc. As Autodesk CFD can be substantially more expensive due to its greater technical abilities, Flow Design may be a more appropriate product for architectural practices.

2.5 Illuminance

What is it:

Illuminance is the measure of how much light falls on a surface. Within Revit it is a tool that enables the analysis of daylighting within a design. It can help designers design spaces that have better levels of natural daylighting.

Why is it important:

Insufficient amounts of natural light can affect mood and the ability to execute tasks successfully. Consequently, rooms may require additional artificial lighting resulting in a building requiring more energy. This tool is important for determining if there is enough light to perform different tasks such as reading, office work and drafting.

How does it work:

Illuminance uses the same engine as Revit's cloud rendering service to produce 3D internal views that illustrate natural lux levels for a design. It can also be used to map lux levels on a plan to understand the impacts of spatial planning on daylighting. It does require a relatively complete model for analysis as material information around reflectivity is required to accurately render internal spaces. Illuminance can also be measured via the 'Insight 360' Plugin.

What to note:

It is not a typical analysis tool, being accessed via Revit's cloud rendering service; a paid service requiring credits to be purchased to undertake each rendered analysis. It is often a balancing act between providing naturally well-lit spaces and ensuring that there are not excessive heat gains and losses from windows. Iteratively testing design strategies via the Illuminance and Conceptual Energy Analysis tools can help identify an optimised solution between heat losses/gains and daylighting.

2.6 Conceptual Energy Analysis

What is it:

The Conceptual Energy Analysis tool in Revit can be used to perform whole building energy simulations using both conceptual masses and/or building elements (i.e. walls, roofs, windows). It helps identify the potential energy use of a design in operation and then allows its comparison to other potential design iterations to help identify the solution with the smallest potential energy requirements. Refer also Section 3.2 SketchUp and Sefaira for Sefaira interface with Revit.

Why is it important:

To minimise our impact on the environment we need to minimise the operational energy of our buildings. This analysis is important as it allows the validity of passive design solutions to be tested and an understanding of the implications of alternative orientations, massing, construction methodologies, material selection, services selection etc. By understanding these factors and their impacts on energy consumption, alternatives can be tested and validated to identify the most energy efficient solution.

How does it work:

The Conceptual Energy Analysis tool uses a cloud based engine to analyse a building's likely energy needs based on predetermined parameters including materials, location, building typology and building usage parameters, that can be edited to varying degrees. Once an analysis is complete it produces a report (Figure 5) displaying climatic and likely energy use data which can be exported as a pdf. Further iterations can be run and compared alongside the original report for direct comparison of alternative solutions. From this, data can be exported to third-party applications for further analysis in a variety of common formats: *gbXML, DOE2* and *EnergyPlus* for use in Green Building Studio, Insight 360 or more powerful analysis tools including *IES* and *Design Builder.*

What to note:

It should be noted when comparing the analyses' results that the graph scales may not relate directly to each other and may need to be recreated in excel, for example, for more accurate and direct comparisons. It should also be noted that though these analyses give great indications of the potential energy use of designs they should only be used as a design tool, and not as a compliance tool for building codes and/or other legislation. Compliance modelling should still be undertaken by suitably qualified professionals using approved software only.

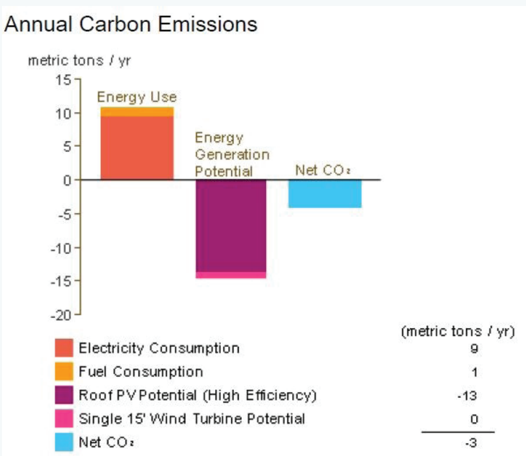
2.7 Green Building Studio / Insight 360

What is it:

Green Building Studio (GBS) and Insight 360 are both online Autodesk portals that allow further exploration of analyses created within Revit. GBS allows users to undertake much more detailed analyses than currently allowed in Revit. For example, the number of glazing and materials scenarios available in GBS vastly outnumbers those available in Revit, meaning designers can further refine their designs. With Insight 360 analyses are similarly uploaded to the cloud where several iterations can be quickly compared in a clear visual manner. Insight 360 also allows the results to be shared and displayed via devices such as smart phones meaning analyses can be compared readily on site or at meetings etc.

Why is it important:

GBS is important as it allows the further refinement of the energy analyses conducted within Revit. It also allows users to explore alternative lighting, *HVAC*, plug loads and built form scenarios to identify the optimised energy solution. Insight 360 is useful for sharing analyses' results particularly when remote from the office with clients, consultants, contractors etc, while its agility allows designers to share simple design iterations quickly.



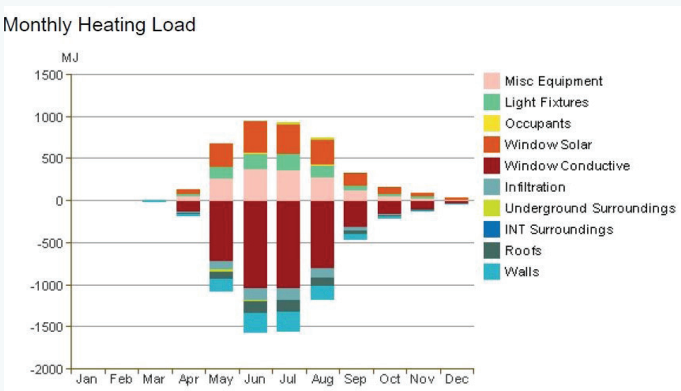


Figure 5. Sample Carbon Emissions analysis (left) and Heating Loads analysis (right) in Revit® (Source: Author, 2017, 'Autodesk screen shots reprinted courtesy of Autodesk, Inc.')

How does it work:

Once an energy analysis is complete in Revit, a gbXML file can be uploaded to the GBS cloud where a set number of analyses are automatically run and results displayed for comparison. With Insight 360 an 'i360' plugin must first be downloaded and installed for Revit. Once an energy analysis has been completed, select the 'I' logo to upload data to the Insight 360 cloud where results can be compared to a limited number of other iterations and/or previous design proposals.

What to note:

For both online portals, an 'A360' login is required which, depending on your license arrangement, may already be established. Also, be careful with cost information displayed within Autodesk products – these are often based on US data and the US dollar and may have little relevance to the Australian or Asian context. Cost data from Autodesk analyses is best kept as design information only and not shared with other parties. Insight 360 is only available for Revit 2016 and later versions.

2.8 Life Cycle Analysis

What is it:

The Life Cycle Analysis (LCA) of a project identifies the potential environmental impact it may have due to the manufacture of materials used in its construction. It looks at a building's location and the materials required to build it, then breaks a material's environmentally damaging characteristics down into a series of attributes including; how much carbon the construction of the building produces, how much energy is required to build it, and other categories including acidification, eutrophication and ozone depletion levels. In undertaking this analysis, design and material selection strategies can be identified that could minimise the impact of a building's construction on the environment. In Revit, the most successful tool in doing this has been the 'Tally' plugin (Figure 6).

Why is it important:

Just as it is important to minimise a building's operational energy, there should be equal determination to minimise the amount of energy a building requires to be built. LCA analyses also allow the minimisation of other damaging impacts of construction, as noted above. Modelling and the ability to accurately assess different material strategies can also enable the challenging of supply chains to create a more environmentally responsible industry.

How does it work:

With the 'Tally' plugin you first need to specify primary materials throughout the design, including structural and finishes elements, therefore this level of analysis is more likely to occur later in the design phase. Material specifications in Revit are linked to similar materials within Tally so that the analysis can be undertaken. Once the initial analysis is complete, the model can be edited by amending material specifications and the analysis rerun to iteratively identify the best performing materials solution.

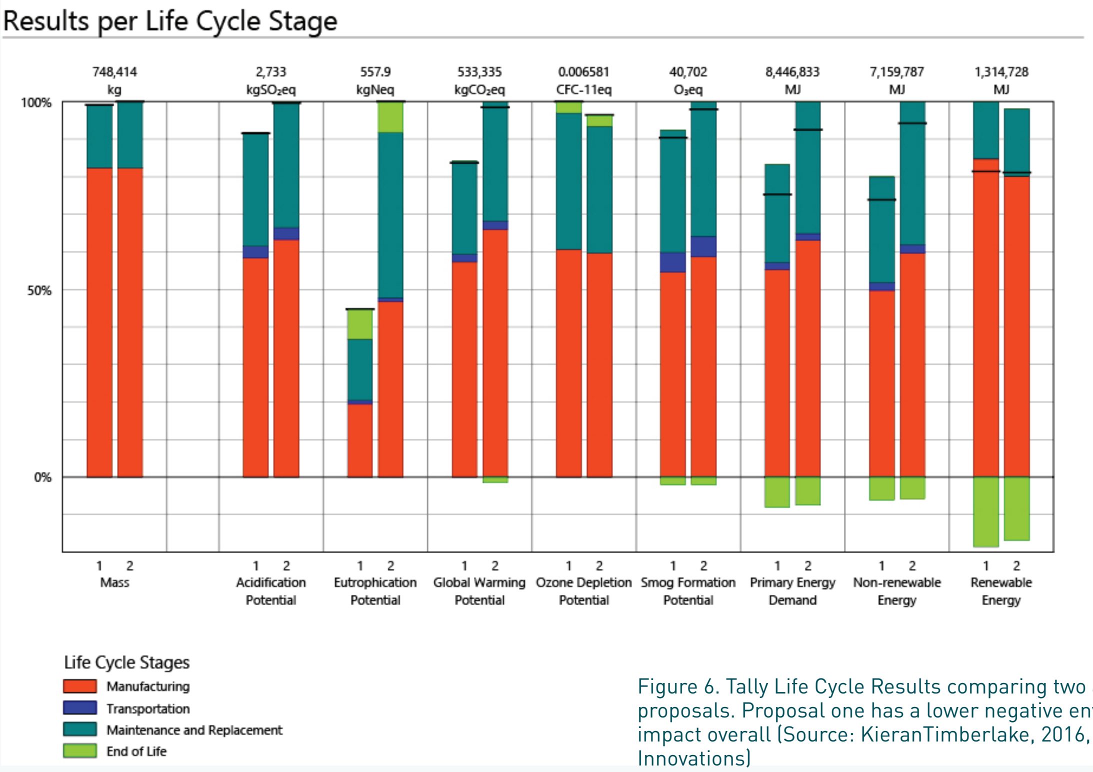


Figure 6. Tally Life Cycle Results comparing two alternative proposals. Proposal one has a lower negative environmental impact overall (Source: KieranTimberlake, 2016, ©KT Innovations)

What to note:
Tally is a third-party plugin that requires a separate purchase. Though not difficult to pick up, it can be time consuming initially to specify all the materials within a model and associate them to Tally values, particularly if it is a large/complex model. The analysis results provide vast amounts of data which may be overwhelming to those not familiar with LCA, therefore, some level of understanding of the issues and processes around LCA is desirable. A free trial of Tally is available at time of writing.

Further information: Tally

2.9 Material scheduling

What is it:
Within Revit there is the ability to schedule materials in many ways including by area, length and volume. By standardising and modularising these, there is the opportunity for instance, to reduce materials wasted on site by offcuts (Figure 7).

Why is it important:
This unitised design approach further reduces the embodied energy and other environmentally damaging attributes of materials as described previously, as well as reducing on site construction waste.

How does it work:
For the construction of a project, materials utilised within a model are standardised in line with those available from industry. When the planning and arrangement of spaces is undertaken, they are designed in line with complete material lengths, areas etc, so that when the building is constructed material wastage is minimised.

What to note:
Though not a typical analysis as per previous tools, unitised material scheduling is an excellent opportunity to minimise environmental impacts through design. It is important that this strategy be considered as early as possible in the building's design as once the spatial areas of a project are locked in there may be little or no opportunity to optimise the efficient use of materials.

2.10 Water

What is it:
Modelling water use is not a current capability within Revit, nor is a plugin available. Nonetheless it is an important consideration of sustainable design. The aim in designing for water is to minimise the water needed to support a building. Water use generally refers to municipal potable water use on the site. It includes the use from fixtures (taps, toilets, sinks, etc.), the use from equipment such as dishwashers, and exterior use for landscaping.

Why is it important:
The efficient use of water is important as it is a natural resource that should be conserved and used sparingly. There are several ways to get the most out of every drop; rainwater harvesting, water-efficient fixtures and equipment, water-efficient irrigation and landscaping and water recycling. Reducing black water (sewage) and grey water (washing machine, shower etc.) discharge can also reduce the loads on municipal systems, therefore requiring less water and energy overall.

How does it work:
Since this analysis cannot be undertaken using Revit, traditional calculations using roof and hard stand areas should be used with rainfall data to understand how much water can be harvested on site (Figure 8), therefore reducing mains water requirements. Specifying highly efficient water fixtures and fittings, and rainwater tanks should also be included.

What to note:
While water analysis cannot be undertaken, there is some ability in Revit to identify the impact on water in specifying different fixtures and fittings in Green Building Studio.

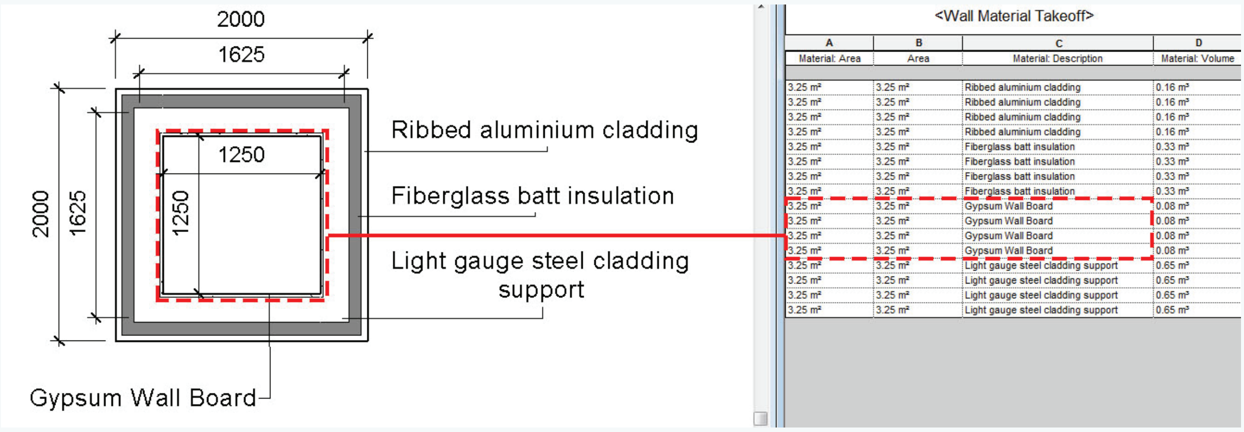


Figure 7. Relationship of floorplan to materials take off within Revit®. Floor plans can be customised to reflect available material lengths, modularisation, etc. to minimise material off cuts (Source: Mielczarek, K. 'Autodesk screen shots reprinted courtesy of Autodesk, Inc.)

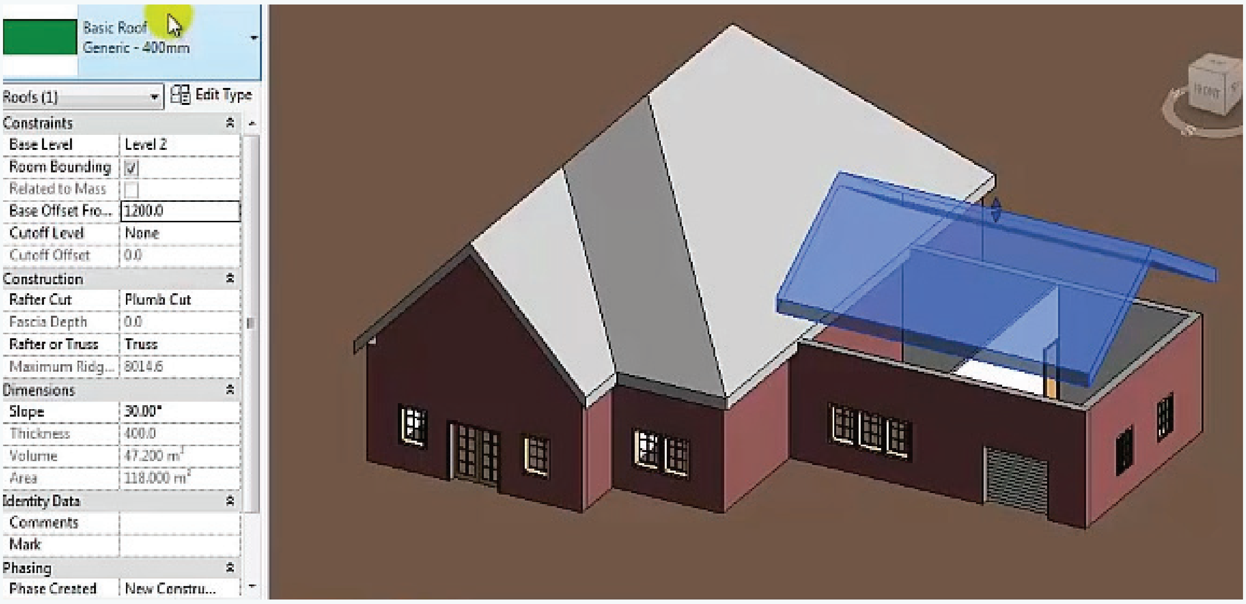


Figure 8. Roof areas can be quickly identified within Revit® for water calculations (Source: BimSrv, 2014, 'Autodesk screen shots reprinted courtesy of Autodesk, Inc.')

Part 3: Alternative tools

3.1 ARCHICAD

Though not as comprehensive as Revit's capabilities, GRAPHISOFT's equivalent 'ARCHICAD' also allows users to undertake certain environmental analyses including: renewable energy, building energy simulation, HVAC design, climate studies and thermal bridging studies of their modelled projects. These analyses form ARCHICAD's EcoDesigner STAR suite which requires a separate paid license, while a basic 'Energy Evaluation' option exists within the standard ARCHICAD program. Other benefits of EcoDesigner STAR include; compliance with ASHRAE (*LEED*) requirements, the ability to export data to more sophisticated analysis tools including IES and Design Builder, more detailed reporting and an ability to compare simulation results directly.

Further information:
https://graphisoft.com.au/ecodesigner-star/

3.2 SketchUp and Sefaira

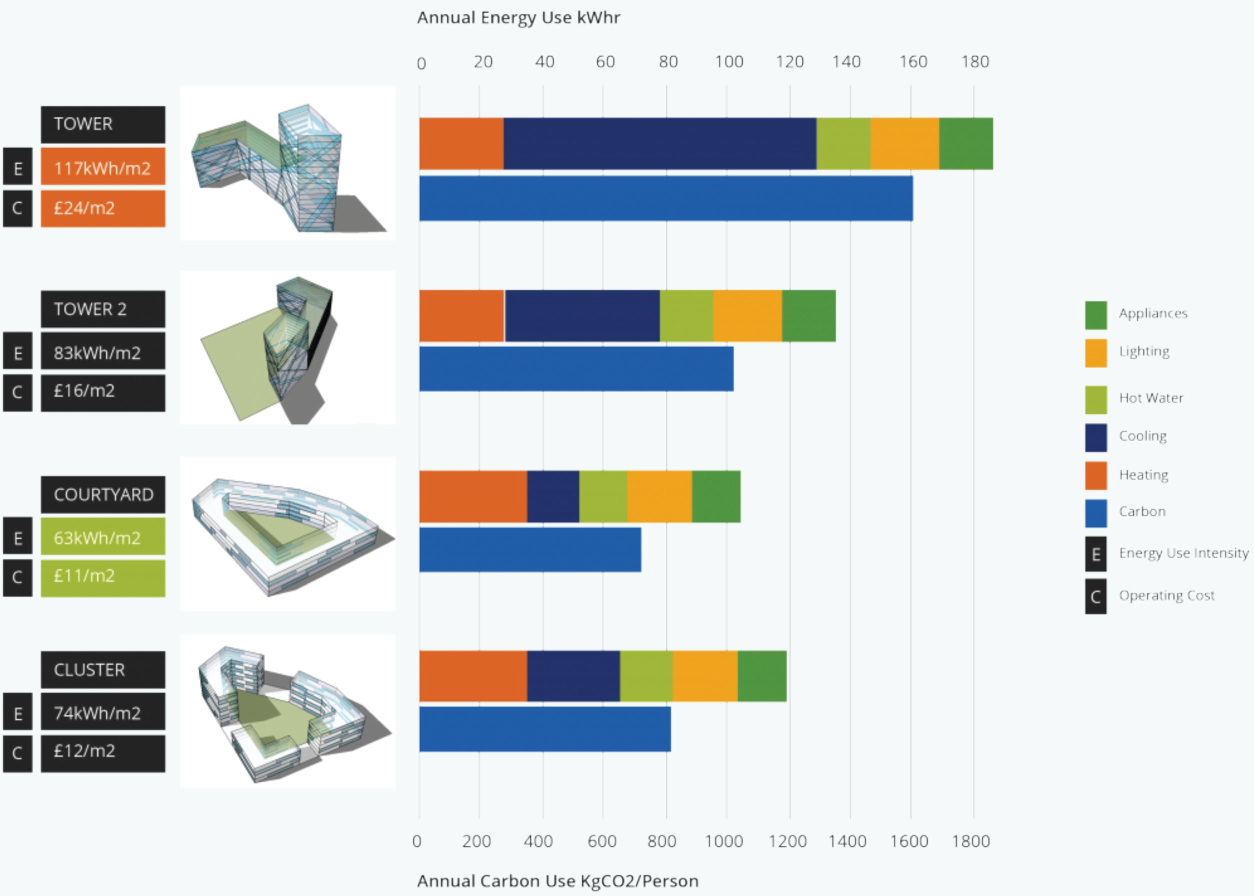
While SketchUp is not a true form of BIM it is a popular design tool amongst architects and designers growing in its sophistication and capabilities. Its ease of use and intuitive learning process allows designers to create models of their proposals relatively quickly.

Sefaira is a paid iterative design tool that can be used with SketchUp from an early stage to optimise a building's environmental performance quickly and easily. Its capabilities include energy and CO2 emissions analysis (Figure 9), daylight analysis and water use calculations. It comes in two forms: Sefaira Architecture and Sefaira Systems, the latter can undertake HVAC design and analysis and is focused more towards engineers.

Sefaira is also available as a paid plugin for Revit, in addition to the analyses tools described previously.

Further information:
http://sefaira.com/sefaira-architecture/

Figure 9 (below). Comparative energy analysis within Sefaira (Source: Sefaira, 2017)



3.3 Climate Consultant

Climate Consultant is a free and powerful non-BIM tool for understanding the climate of approximately 69 locations around Australia and many more globally. Reliable EnergyPlus weather (EPW) files for a location are downloaded separately for free and loaded into the software. Once complete, data is then graphically represented through various charts and graphs to explain historical averages for the set location. Possibly the most powerful tool within Climate Consultant is the *Psychrometry* Chart (Figure 10) which explains human comfort levels for a location, allows selection of certain time periods for analysis and then links them to the most effective passive design to help increase *occupant thermal comfort*.

Further information: http://www.energy-design-tools.aud.ucla.edu/climate-consultant/request-climate-consultant.php

3.4 THERM

THERM is a small non-BIM standalone and free software that allows designers to assess the thermal performance of construction details to minimise thermal bridging. This is important as thermal bridging can be one of the biggest sources of unwanted heat loss and gain in a building's fabric and can lead to increased energy use and potentially condensation and mould growth. THERM works by importing a 2D CAD detail and associating thermal conductivity values to each of the materials within the construction detail. Internal and external temperature values are set and once the analysis is completed results are visualised as a heat flow through the detail identifying potential weak spots that could enable thermal bridging once constructed (Figure 11).

Further information: https://windows.lbl.gov/software/therm/therm.html

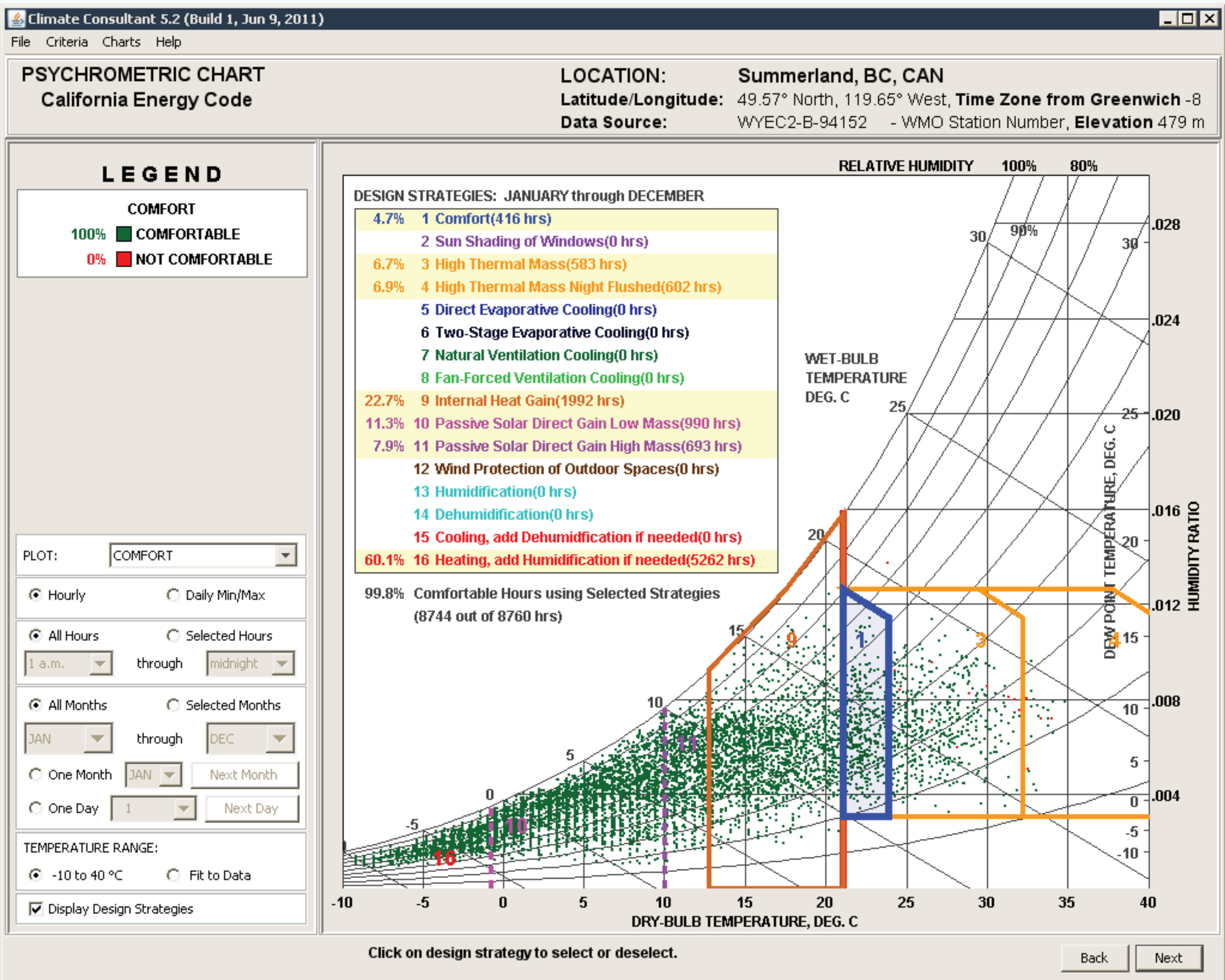


Figure 10. Sample Psychrometric chart from Climate Consultant showing comfort range (1 – 'blue area') (Source: Voshage, J. 2011)

3.5 COMFEN

Like THERM, COMFEN is another small non-BIM standalone and free software that can allow designers to assess the performance of fenestration systems for commercial buildings. It particularly assesses the impact of fenestration variables on the energy consumption, peak energy demand, and thermal and visual comfort of a space, graphically representing results. It does require basic spaces to be modelled within the software which means the process is not as fluid as some of the other tools discussed, however its use helps to understand the relationships between the thermal and visual comfort of a space.

Further information: https://windows.lbl.gov/software/comfen/comfen.html

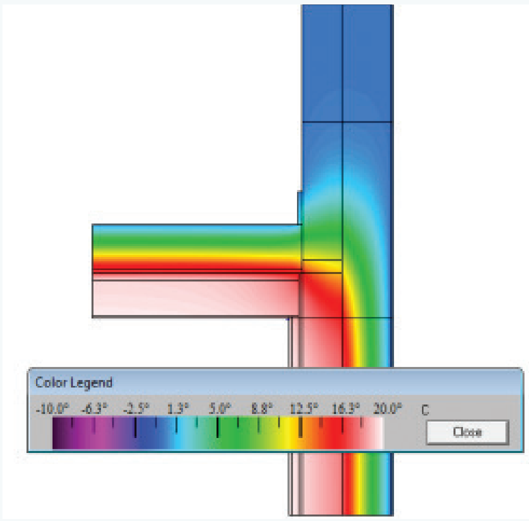


Figure 11. Heat transfer through typical roof/wall junction in THERM software (Source: WARM, n.d.)

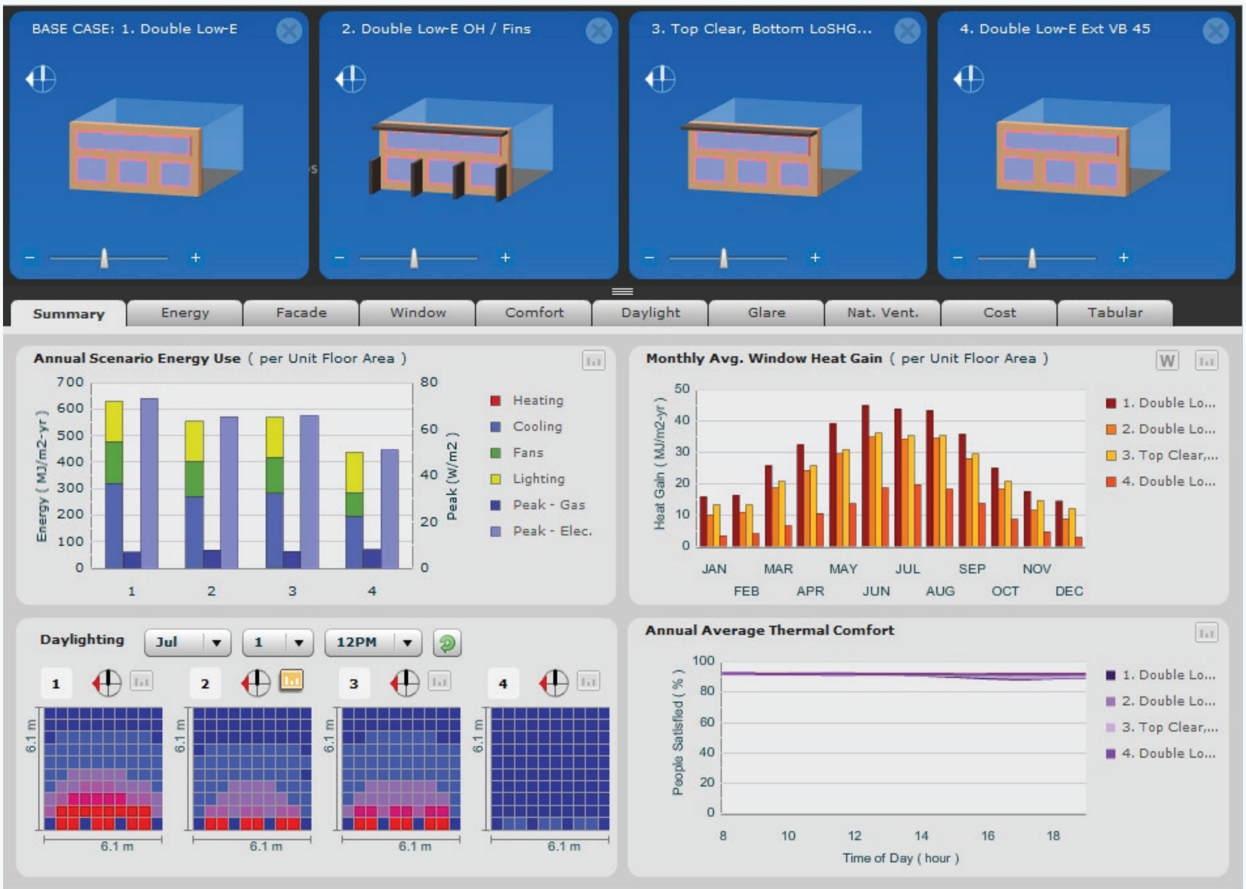


Figure 12. Facade analysis with COMFEN (Source: CBERD, 2016)

3.6 Revit and Dynamo/Rhino and Grasshopper plugins

3D modelling software is extremely popular among designers and there are many preferred tools available online. Rhino is a powerful tool to model and render proposed designs with Grasshopper, an open source algorithmic modelling or 'visual programming' language for Rhino, allowing users to effectively 'program' designs. As anyone can create custom analysis plugins for Rhino and Grasshopper, its tools are now amongst some of the most sophisticated and accurate available. Additionally, their capabilities are set to grow exponentially due to the current uptake of the software and its ability to be customised as needed.

Similarly, *Dynamo* is available to enable algorithmic design within the Revit environment.

Both Revit/Dynamo and Rhino/Grasshopper now have several useful and powerful environmental analysis scripts including:

Ladybug

Allows designers to import and analyse standard climate data in Dynamo/Grasshopper; draw diagrams such as sun-paths and wind and radiation roses; customise diagrams in several ways and run radiation analyses, shadow studies, view analysis etc. (Figure 13)

Honeybee

Connects Dynamo/Grasshopper3D to validated simulation engines to undertake analyses including energy use, comfort, and daylighting and lighting simulation.

Dragonfly

Can be used to study the effects of urban heat island effect and other environmental and built form factors on thermal comfort within Dynamo/Grasshopper.

Butterfly

This plugin can be used to undertake CFD analysis of designs within Dynamo/Grasshopper.

Further information:
https://www.rhino3d.com/,
http://www.grasshopper3d.com/
and http://www.grasshopper3d.com/group/ladybug

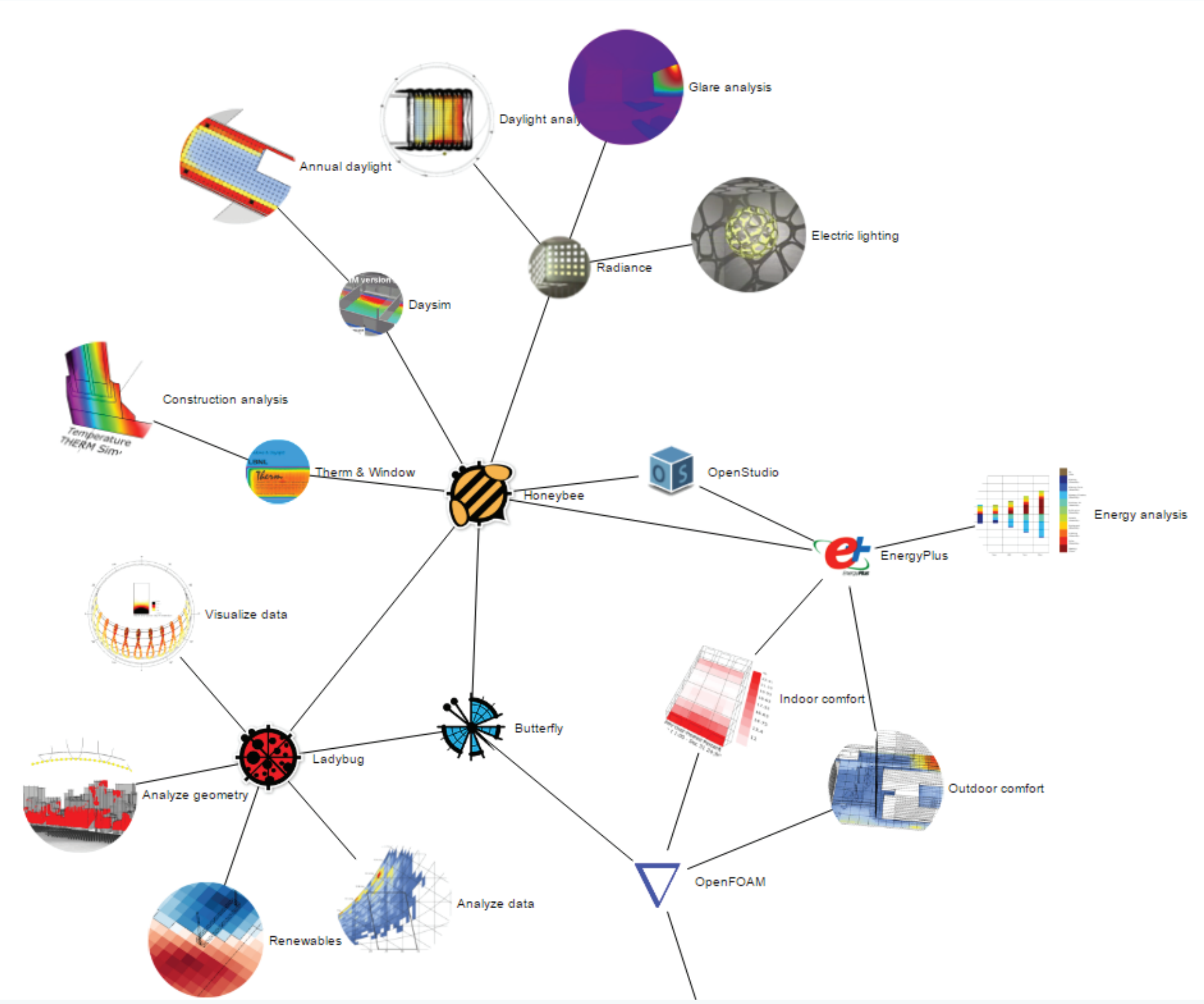


Figure 13. Rhino analysis map with 'Ladybug', 'Honeybee' and 'Butterfly' plugins (Source: Ladybug tools, n.d.)

Considerations beyond BIM

Quantitative and qualitative data

BIM provides many opportunities to enable sustainable design outcomes, from energy analysis to thermal comfort to thermal bridging. However while this presents vast amounts of useful data, it is all quantitative in nature.

As architects and designers, it is our responsibility and opportunity to design for the human factor. To do this we must truly understand the qualitative side of sustainable design. When designing don't forget to consult with the client on their perceptions; while they might for example agree that a wind generally comes from one direction during the year, there may also be a hotter or colder wind that provides greater discomfort and only occurs occasionally that they would prefer protection from. These insights are invaluable in sustainable design.

Similarly, sustainable design within BIM mostly focuses on the environmental aspects of sustainability. Social and economic considerations of a client/user group should also be carefully considered for truly sustainable outcomes to be achieved.

Evolutionary not revolutionary

The content explored in this note is, in general, nothing new. Environmental design has been a fundamental of the architects' skillset for centuries and designing in response to climate is effectively building physics, with challenges solved through analysis and design. What has changed is our increased ability to understand challenges of greater complexity, visualise them and their solutions and resolve them at a much quicker rate.

As the capabilities of BIM evolve and accelerate it will be important to continually update organisational skillsets and capabilities, as already seen with the explosion of Rhino, Grasshopper and algorithmic design. However, the fundamentals of environmental design will not change and it is critical that these are understood in order to legitimately apply these tools. Environmental analysis may also be undertaken outside of BIM as BIM may limit, or over influence, the freedom of geometrical/formal expression.

Conclusion

In conclusion, it is apparent that multiple sophisticated tools are available within BIM for designers to create sustainable designs. However careful consideration must be given to how BIM and environmental analysis is applied within an organisation based on its size and BIM capabilities. Similarly, this note identifies several software packages and methodologies available to organisations to undertake environmental analysis and ultimately the most appropriate analyses will depend on the organisation's BIM and sustainability capabilities as well as the level of analysis they wish to achieve. Environmental analysis should be undertaken as early as possible, as part of the design process, and used iteratively throughout so that the most optimised design solutions are identified.

This note also draws attention to the fact that these software packages are only 'tools' at best and there are many other considerations that designers must include when creating sustainable design solutions including qualitative data, understanding the fundamentals of environmental design and economic and social considerations.

Ultimately this is an exciting area of design that puts greater sustainable design solutions closer to the fingertips of designers in a way that was not previously possible.

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Glossary

ARCHICAD – BIM software created by GRAPHISOFT

AutoCAD – Vector based software that in the Architectural profession is predominantly used for 2D documentation

Autodesk – Creators of AutoCAD and Revit

BIM – Building Information Modelling, allows for the design, coordination, documentation, rendering and analysis of buildings

Design Builder – Standalone environmental analysis tool. Export plugins are available for Revit

Direct solar heat gains – Direct solar radiation received by a surface from the sun

DOE2 – A freeware building energy analysis program that can predict the energy use and cost for all types of buildings

Dragonfly – Grasshopper plugin for climate data generation and manipulation, can be used to model Urban Heat Island effects, future climate scenarios, etc

Dynamo – Algorithmic modelling Autodesk plugin and software for Revit

Ecotect – Now defunct environmental analysis tool acquired by Autodesk and utilised to create environmental analysis tools now found in Revit

EnergyPlus – A whole building energy simulation program that engineers, architects, and researchers use to model both energy consumption—for heating, cooling, ventilation, lighting and plug and process loads—and water use in buildings

gbXML – 'Green Building XML' – a file type that allows the transfer of energy/geometry/etc. data from one software to another

Grasshopper – Algorithmic modelling software for Rhino

Honeybee – Grasshopper plugin for environmental analysis, can be used to model building energy, comfort, daylighting and lighting simulation, etc

HVAC – Heating, ventilation and cooling systems

IES – Standalone environmental analysis tool. Export plugins are available for Revit

Indirect solar heat gains – Heat gains received through diffusion or reflection, e.g. clouds and reflective surfaces

Ladybug – Grasshopper plugin for environmental analysis, can be used to model run radiation analysis, shadow studies, view analysis, etc

LEED – Leadership in Energy and Environmental Design, American equivalent to the Green Building Council of Australia's' Green Star system

Occupant thermal comfort – How comfortable a space feels from a thermal perspective for the average person

Psychrometry – The study of human thermal comfort

Revit – BIM software created by Autodesk

Rhino – Non-BIM 3D Modelling software

SketchUp – Non-BIM 3D Modelling software

About the Author

Rory is a registered architect and holds an Honours B.Arch and MSc with distinction in Environmental Design, as well as having completed the Autodesk Building Performance Certificate. For the past 10 years he has worked in Canada, the UK, Vietnam and Australia in architecture, development and sustainability roles.

He has spoken at numerous events around Australia and overseas on BIM and sustainability and is a regular contributor to the Australian Institute of Architects, the Property Council of Australia and the Green Building Council of Australia on sustainability issues. In 2014 he was awarded the inaugural 'Future Green Leader' Award by the Green Building Council of Australia for young peoples' contribution to sustainability in the property and construction industry.

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