Towards a BIM-Based Energy Rating System

Comparisons between FirstRate5 and ArchiCAD EcoDesigner

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Abstract. Governments in Australia are faced with policy implementation that mandates higher energy efficient housing (Foran, Lenzen & Dey 2005). To this effect, the National Construction Code (NCC) 2013 stipulates the minimum energy performance for residential buildings as 114MJ/m² per annum or 6 stars on an energy rating scale. Compliance with this minimum is mandatory but there are several methods through which residential buildings can be rated to comply with the deemed to satisfy provisions outlined in the NCC. FirstRate5 is by far the most commonly used simulation software used in Victoria, Australia. Meanwhile, Building Information Modelling (BIM), using software such as ArchiCAD has gained a foothold in the industry. The energy simulation software within ArchiCAD, EcoDesigner, enables the reporting on the energy performance based on BIM elements that contain thermal information. This research is founded on a comparative study between FirstRate5 and EcoDesigner. Three building types were analysed and compared. The comparison finds significant differences between simulations, being, measured areas, thermal loads and potentially serious shortcomings within FirstRate5, that are discussed along with the future potential of a fully BIM-integrated model for energy rating certification in Victoria.

Keywords. Building Information Modelling, energy rating, FirstRate 5, ArchiCAD EcoDesigner, Building Energy Model.

1. Introduction

Whilst there is a governmental initiative in Australia for more sustainable green residential buildings (Drogemuller 2012), the current status is well be-
low the worldwide standard (Horne, et al. 2005). This will require radical policy change and adherence to meet the 2020 emission targets set at the Kyoto Protocol commitment of limiting emissions to 108 per cent of 1990 levels (Carter 2010).

The Federal and State governments in Australia are continually implementing policy that mandates higher energy efficient housing (Foran, Lenzen & Dey 2005). The National House Energy Efficiency Standards are prescribed in the National Construction Code 2013, (NCC 2013) which stipulates the minimum energy performance requirements for a residential building. In order to evaluate these, minimum performance requirements software has been designed to rate thermal performance requirements.

The current software used in Victoria is FirstRate5. As a post design evaluation system FirstRate5 relies on certain assumptions and their understanding of what makes a building efficient in order to attain the minimum performance requirements.

In order to overcome the inefficiencies of redesign, ‘in design’ modelling and performance evaluation has been integrated into building information modelling software such as ArchiCAD v17 with EcoDesigner. Building information modelling (BIM) has revolutionised the way architects design with parametric objects and Geometric Description Language (GDL) elements which contains all the necessary information for structural, cost and thermal dependencies.

This paper will address the relationship between ArchiCAD EcoDesigner and FirstRate5 in relation to energy analysis and determine if correlation exists between the two simulation programs. Addressing the conference theme of Comprehensive Design, we pose the question: ‘What is the relationship between FirstRate5 and BIM-based systems (ArchiCAD EcoDesigner) as a tool for comprehensive design for energy evaluations?’

2. Energy Evaluation Case studies

2.1. FIRSTRATE5 AND ARCHICAD ECO DESIGNER WORK FLOW

The FirstRate5 work flow is centred around the use of .pdf documents received from the draftsperson or architect at the documentation stage of the project. The pdf is loaded into FirstRate5 then orientation levels and scaling are applied to the drawing. Approximate zones and areas are then overlaid for each area, i.e. day and night use, kitchen and bedroom and fenestration information is added. From here, the estimated insulation is applied and the star rating is calculated by the FirstRate5 software. If the rating falls below
6 stars, the architect is advised of the need for adjustments to materials and insulation until the required rating is achieved (see figure 1, left).

ArchiCAD EcoDesigner workflow integrates the means of drawing production with the energy analysis via the BIM model, beginning with the iterative development of an ArchiCAD building from the initial design concept through to schematic design, design development and documentation stages. As the integrity of the energy rating is directly related to the quality and accuracy of the CAD model, considerable time, energy and cost is required to input into the model. All building elements that inform the model, including floor, wall and roof materials, door and window types are required to be accurate and correct.

From here, zones are then defined by use and occupancy data such as hourly use, equipment, lighting and hourly temperatures can be entered. Lo-
cation and climates data is downloaded from the Strusoft website and any mechanical heating and cooling is selected. Once all the zones have been updated with this information, the simulation can begin. At this stage if the energy performance of the building falls below the required statutory performance more insulation or changes to the BEM model can occur.

2.2. THREE CASE STUDIES

We utilise three residential case study buildings designed for Melbourne, Australia to test and compare FirstRate5 and ArchiCAD EcoDesigner. These case studies were chosen to represent the range of residential buildings common in Victoria, Australia. Each case study building was evaluated using both FirstRate5 and ArchiCAD EcoDesigner for heating load, cooling load and total energy loads. Data from both programmes was analysed to determine the differences in output from the three case study types, with a snapshot of the comprehensive study reported here.

Case Study 1: 115.07 sq.m. 2 bedroom 8th and 9th floor apartment located in Melbourne Victoria with orientation north to north-west. The building is comprised of concrete in situ walls and floors, open plan living with living on 8th floor and bedrooms on 9th, no insulation material and full height glazing to the only north-north west facade.

The report generated by FirstRate5 summarises the energy loads and measured area based upon the simulations inputs. The 3.7 star rating is indicative of the total energy load of 213 MJ/m² and describes how the apartment would thermally perform in a climate zone that is mostly protected from environmental elements.

The report generated by EcoDesigner for the apartment design indicates that the energy loads for heating is relatively low at 13.11MJ/m² per annum. The generated report above also indicates that yearly the cost would be $2,200 with carbon emissions of 2,908 kilograms.

Case Study 2: 152.13 sq.m. Single storey 3 bedroom house located in Melbourne Victoria with orientation to north and comprising elevated timber weatherboard cladding to insulated stud frame with insulation. The predominant glazing direction for this building was to the south living areas due to the block orientation. FirstRate5 reported the energy loads totalling 113.4 MJ/m² based on the conditioned area of 105.1 m². The unconditioned area is not relevant to this simulation as it does not incur any thermal loads. The EcoDesigner report shows a significantly higher heat load for this building than the apartment Case Study 1. This dwelling will require more heating and less cooling, with the building shell performs at 19.70J/m²K. This is a
good indication of the overall external thermal fabric matrix provided by the selected materials.

Case Study 3: 229 sq.m. Double storey, three bedroom house located in Melbourne, Victoria with orientation to West and comprised of brick veneer cladding on timber stud walls with insulation on a concrete slab. This dwelling has open plan living on ground and bedrooms on first floor with majority of glazing to the east. The total energy load for the double storey house is defined by Firstrate5 at 165 MJ/m² and illustrates a proportional increase in energy usage as the floor area increases (from Case Study 2). The FirstRate5 report is based on the measured conditioned area of 178 m². The EcoDesigner report for Case Study 3 identifies a slightly higher energy loading than the single storey Case Study 2, based on materials and climate data that were downloaded directly into EcoDesigner.

Table 1 below provides a summary of floor areas, heat load and cooling loads for the case studies for both First Rate 5 and ArchiCAD EcoDesigner. Table 2, provides a summary of total energy loads and differences between First Rate 5 and ArchiCAD EcoDesigner.

### Table 1: Heating and Cooling Load Results

<table>
<thead>
<tr>
<th>Typology</th>
<th>Area m²</th>
<th>Heat Load MJ/m²</th>
<th>Cooling Load MJ/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment</td>
<td>119.9</td>
<td>109.54</td>
<td>14.48%</td>
</tr>
<tr>
<td>Double Storey</td>
<td>178</td>
<td>207.24</td>
<td>30.74%</td>
</tr>
<tr>
<td>Single Storey</td>
<td>105.1</td>
<td>144.96</td>
<td>39.78%</td>
</tr>
</tbody>
</table>

### Table 2: Heating and Cooling Load Results

<table>
<thead>
<tr>
<th>Typology</th>
<th>Total Energy Load MJ/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment</td>
<td>213.6</td>
</tr>
<tr>
<td>Double Storey</td>
<td>150.3</td>
</tr>
<tr>
<td>Single Storey</td>
<td>113.3</td>
</tr>
</tbody>
</table>

3. Traditional vs BIM-based Energy Modelling

The case study is limited in scope, however provides a small insight into some of the fundamental shortcomings of the most accepted energy rating method used in the state of Victoria, Australia. Analysis of the results finds that, although the Single Storey dwelling has the greatest difference in measured area between FirstRate5 and EcoDesigner (37.87%), it also had the lowest difference in total heating and cooling and total energy loads. The Double Storey dwelling has the closest correlation between measured area...
(16.43% difference) and total energy load (21.98% difference). The apartment dwelling, although having a similar measured area to the Double Storey dwelling (14.48%), reported a significant spike in total energy load difference between FirstRate5 and EcoDesigner (72.28%).

Figure 2, below illustrates the differences between FirstRate5 and ArchiCAD EcoDesigner in relation to both area and total energy load calculation. The differences in area on the X axis and total energy loads on the Y axis are illustrative of the outcome of the comparative study across the three dwelling types.

![Total Energy Loads by Area](image_url)

*Figure 2: Comparison of total energy loads by area*

### 3.1. FIRSTRATE5

The simple issue of the energy rater’s judgement of the thickness of a line may be resulting in a massive error in energy calculations across a wide number of projects. Ultimately, it is the abilities and judgement of the rater that impacts the rating. The energy rater generally obtains a pdf set of drawings from the architect or building designer, and then pastes this image into the background interface of Firstrate5. This image is then scaled to form the basis of the rating. If a wall line is drawn with a 1.0mm pen thickness and the rater chooses to use the centre, outside or inside line of the wall lines on the plans, this builds in a potential error in wall thickness of 50mm to 100mm. If this error is multiplied by the perimeter of the building or zone, a
substantial area calculation error may result between the designer’s intended area and the measured area that is inputted into FirstRate5.

Generally, FirstRate5 ratings operate on business model that relies on quick completion and high turnover, based on a price of between $250 and $400 per rating, which may buy 1-2 hours work. In this competitive, cost-driven environment, there is little room for a lot of time to be spent on checking the accuracy of line work. As different energy raters work differently, one rater may always work to the centre line and another always to the outside, resulting in two different ratings.

Further to this, for two storey designs, upper floors must be aligned above each other, otherwise floors below will be interpreted by the programme as uncovered and hence cause thermal loss and gain. Once multiple storeys have been aligned and scaled the areas and zones are overlaid by sight approximately over the PDF. This is not done by measurement.

In our case study, we recorded variations in floor area between Firstrate5 and ArchiCAD EcoDesigner of up to 37% in area measured, based on the use of a dimensionally accurate ArchiCAD model. This highlights the potential for fundamental flaws in Firstrate5, which may result in substantial inaccuracies in thermal load calculations. When making adjustments for area discrepancies, FirstRate5’s energy loads were higher than EcoDesigner. This may indicate the inaccuracies noted above and or may indicate that the supporting data that informs the simulators engine is inaccurate or incomplete. The choice of materials and fenestration elements is limited by the FirstRate5 simulator library. If innovative of non-standard materials are to be used then the user must make assumptions, approximate and select the closet material or element to that specified.

This is compounded by FirstRate5’s inability to accurately plot out complex structures because it operates on a straight-line basis only. Curved walls need to be inputted as a series of straight lines approximating the curve, increasing the margin of error. FirstRate5 does not allow for complex, barrel vaulted, cathedral ceilings or other commonly used roof forms. This is a function of FirstRate5 being implemented to satisfy the mass production housing market in Australia, resulting in the programme having limited capacities for complex, architect-designed projects.

3.2. ARCHICAD ECODESIGNER

Since the invention of paper in the 16th century architects have represented design through drawings (Kvan 2001), as a descriptive set of projections that operate in a geometrised, homogenous space that is construed as a real space of human action (Perez-Gomez and Pelletier 1997). BIM has evolved
from the early iterations of 3D CAD as the ‘profession moves beyond traditional practice and its drawing-centric model into a dynamic process/component oriented model for digital practice and the subsequent re-definition of professional services and contractual deliverables’ (Ambrose, 2009).

The workflow of EcoDesigner in ArchiCAD 17 allows the user to accurately model any residential typology and accurately and automatically place zones that are millimetre perfect in plan and volumetrically. It is this intrinsic accuracy of the model that results in a greater accuracy of the energy rating done by EcoDesigner. The integrity of the BIM model comes, however, at a significant cost as the output potential of the BIM model is only as good as the input, which is only as good as the user. The ability of EcoDesigner to handle complex structures and materials allows for greater accuracy when simulating energy loads. Although the process for achieving a simulation is more complex than that of FirstRate5, the payoff is that the results are more accurate if the data used and entered is correct.

Potential areas for error include the completion and sealing of wall elements, resulting in EcoDesigner interpreting rooms as being open and exposed. The BIM model requires accurate thermal properties for each material to be inputted into walls, floors and roof elements as well as doors and windows. This is a lot more work, time and cost and requires in-house expertise and skills over and above traditional manual drawing or 2D CAD (AutoCAD) drawing production.

4. Implications of the study

Our study finds shortcomings in the use of both FirstRate5 and ArchiCAD and EcoDesigner for energy analysis. Ultimately, further research is required to validate these early findings with post-occupancy energy evaluation, however this is outside the scope of this paper. Although FirstRate5 is quick, easy to use and can rely on the input of a wide range of designers, from builders and draftspersons to architects, the methodology may result in a wide discrepancy between the designers intention and the rater’s judgement. This inaccuracy may result in over, or under performance against the required standard. FirstRate5 was introduced to cater for the mass market of building construction in Australia and it’s requisite composition of simple, easy-to-build and cost-effective materials, structural systems and building forms. Architects, especially those who may aspire to bespoke, complex and innovative buildings, may find their FirstRate5 ratings to be inaccurate, as a result of the time-poor, cost-driven and skill-limited energy rater’s approximation that is compounded by the limitations in the programme itself. As
FirstRate5 raters charge for each rating, there is a disincentive for architects and clients to engage in multiple, iterative ratings of a dwelling.

Currently, FirstRate5 energy analysis is required only at the Building Permit stage—after Schematic Design, Design Development and the Planning Permit stages. The incorporation of EcoDesigner into the design workflow will reduce time and cost of rework prior to town planning submission and greatly increase the ability to produce far more thermally efficient dwellings. The demand for more information at the early stages of BIM modelling will also require more ‘embodied effort,’ (Ham, 2013) which will ultimately increase the cost of architectural services. This increased cost could be offset by time savings resultant from obtaining energy information in the early design stages via the BIM-based methodology in Figure 3, below.

![Figure 3: BIM-based design and evaluation methodology](image)

The greater potential of using a BIM to BEM simulator such as EcoDesigner for Victoria and Australia is the ability to supersede simulators such as Firstrate5 and others which are limited in their capacities. If EcoDesigner does manage to supersede Firstrate5 in Victoria then the implications will be wide ranging. The ability to produce accurate and consistent ratings in-house and via an iterative process where energy data feeds into the design will be enabled, which will result in greater efficiency in thermal performance as the simulation is completed prior to town planning submission and before the final design is submitted for approval. We propose a future where architects regain the territory lost to mass-market builders by leading the engagement in BIM-based simulators for utilised in residential architec-
tural design, creating an optimised building rather the reacting to post design thermal inefficiencies (Hetherington, Laney & Peake 2012). The question is, is the industry ready for this, or will it take another 30 years of CAAD to realise the potential of the building information model?

References