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Improving thermal performance design outcomes through NatHERS and BIM integration

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Abstract: The Nationwide House Energy Rating Scheme (NatHERS) has played a significant role in demonstrating the thermal performance compliance of residential buildings in Australia. However, NatHERS tools are rarely used during conceptual analysis to help iteratively improve and optimise the performance of buildings throughout the design process. A significant contributor to the lack of adoption in the design process is the user interface of these tools, which rely on manual data input, making them incompatible with typical Building Information Modelling (BIM) workflows. This paper describes a working software prototype called *SketchuRATE* that has the potential to convert BIM data directly into the AccuRate Sustainability file format, minimising the need for manual data entry or duplication. Once fully functional, a tool like *SketchuRATE* could shift the focus of house energy ratings away from achieving only minimum compliance, towards more economical, optimised and improved thermal performance outcomes.

Keywords: NatHERS, building compliance, thermal analysis, BIM.

1. Introduction

Since 2003, the Nationwide House Energy Rating Scheme (NatHERS) and associated software has played an increasing role in demonstrating the thermal performance compliance of residential buildings in Australia. According to the NatHERS Administrator, it is estimated around 70 percent of new dwellings in Australia are assessed using a NatHERS tool to demonstrate energy efficiency compliance under the National Construction Code (NatHERS, 2015). In the 2014-2015 financial year, this represented over 150,000 dwellings per year (derived from Kalisch, 2016).

However, because of the emphasis on compliance, NatHERS tools are rarely used as part of the design process to iteratively improve the thermal performance of the final design (even though that is invariably the only thermal analysis undertaken of the design). This situation is exacerbated by the user interface of these tools, which all rely on some form of manual data entry of building information from architectural drawings and specifications, in order to complete a house energy rating.

A perhaps unintended consequence of this process is that the role of the thermal performance assessor has become more about data entry rather than the provision of thermal performance advice. What started as a cottage industry of individuals passionate about building sustainability has slowly deviated into a high volume, low cost operation where a handful of larger companies churn out tens of thousands of assessments each year. In turn, the focus appears to have shifted towards achieving the first minimum compliance outcome, as opposed exploring all options to genuinely improve and optimise a dwelling's thermal performance.

Concurrently, there has been increasing uptake of Building Information Modelling (BIM) workflows within the building and construction industry. According to a 2010 study commissioned by the Built Environment Innovation and Industry Council, the "accelerated widespread adoption of BIM technology" is likely to have a "significant expansionary effect on the Australian economy" - an increase in GDP of between $4.8-7.6 billion over the 2011-2025 period (Allen Consulting Group, 2010).

Given the rich database of information available in a typical Building Information Model, there is significant potential to develop a workflow or methodology that could facilitate the use of this building information for the purposes of evaluating a building's energy efficiency compliance. If successful, it is envisaged this would eliminate the unnecessary, manual duplication of data from architectural drawings and specifications into NatHERS tools. In turn, this could shift the focus of house energy ratings towards optimised or improved performance outcomes, not just minimum compliance. Streamlining the delivery of compliant energy efficiency outcomes also has the potential to reduce lead times and/or construction costs for clients in the procurement of new residential buildings.

The integration of energy and thermal performance analysis into a BIM-based workflow is not a new idea. Numerous papers have previously highlighted the benefits of this approach, such as allowing dynamic energy simulation and continuous verification of performance over a building's entire life cycle (Laine & Karola, 2007). Other publications have also identified the challenges involved, such as a need for validation of the analysis model and additional information apart from building geometry (Moon et al, 2011).

This paper provides an overview of a proof-of-concept tool we have been developing, known as *SketchuRATE*, and the progress made to date in addressing some of these challenges in the Australian context.

2. What can be improved with the current approach to NatHERS?

It is important to note that this paper is not about the "accuracy" of the CHENATH engine upon which all current NatHERS tools are based. While there have been papers previously published questioning the effectiveness of NatHERS (Williamson, 2001), there have also been papers that validate its methodology (Delsante, 2004; Dewsbury, 2015; O'Leary et al, 2016). This paper assumes that NatHERS is a valid approach for estimating heating and cooling household energy consumption. Consequently, it focuses on improving the workflow integration of house energy ratings with the design and documentation of residential buildings using BIM.

Figure 1 illustrates the typical workflow required to complete a house energy rating on a single dwelling. Based on this workflow diagram, we have identified three opportunities for improvement in relation to the accuracy and/or time required to conduct house energy ratings:

- Significantly reduce duplication of key building information;
- Minimise or eliminate data entry inconsistencies; and
- Allow more time to improve building design and thermal performance outcomes.

2.1 Avoidable Duplication of Building Information

In order to conduct a house energy rating, dimensional data must be inputted into the rating software. This typically includes wall lengths and heights (external and internal), floor, ceiling and roof areas, door and window opening areas, and volumes of functional zones within the building. Building and construction materials also need to be specified in the rating software.

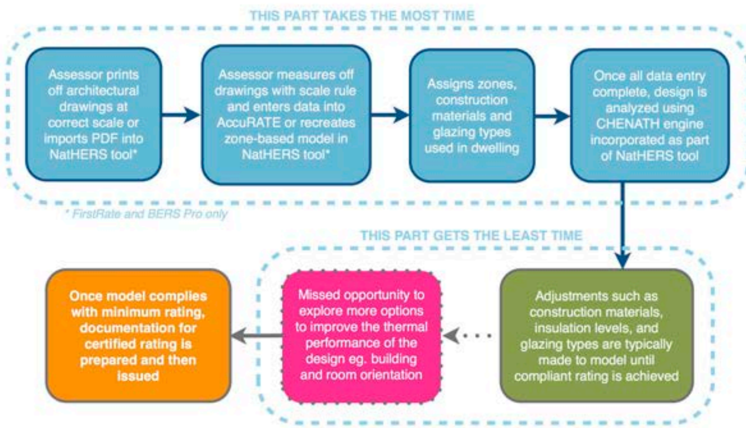

Figure 1: Typical workflow for conventional approach to House Energy Rating.

With all three software tools currently available for conducting a NatHERS assessment, all of this data and information needs to be manually entered into the rating software. While some tools such as FirstRate and BERS have limited capabilities to import PDF documents that can be traced over digitally, currently there is no direct connection between NatHERS tools and existing CAD/BIM software applications. If the design changes in any substantive way, much of this information has to manually edited or entered again to reflect those changes.

However, all of this dimensional, area and volumetric data already exists in a typical BIM or gbXML model; these models can also contain information regarding proposed construction materials and their associated properties. Given the ready availability of this building information, extracting and manually entering this information into the rating software seems a time-consuming and laborious exercise that is prone to error.

2.2 Inconsistency of Data Entry

Accuracy of data entry appears to be the area of greatest unreliability with house energy ratings completed using existing workflows. A 2014 benchmarking study conducted on behalf of the

Commonwealth Department of Industry found that in a statistically significant sample of assessors, 64% of assessors had an error greater than 0.25 of a star (Floyd, 2014). The study also found:

- errors increased significantly with the increasing complexity of [house] design and documentation;
- 25% of assessments reported incorrect window areas;
- the [calculated] area of different wall constructions and floor coverings … showed error rates ranging from 10 to 70%; and
- [A variety of errors] indicated the lack of a systematic approach to the rating process by assessors.

These findings can be plausibly attributed to erroneous interpretation of the architectural drawings, construction specifications and/or mistakes when entering into the rating software. All of these are the direct responsibility of the assessor, which suggests changes to the NatHERS workflow that minimize or eliminate the possibility of data entry errors may help to improve the accuracy of house energy ratings.

2.3 Allow more time for optimising building design and thermal performance outcomes

The automatic generation of input aims to avoid unnecessary duplication of effort and substantially reduce data entry errors, allowing more time to review the thermal performance and compare options or explore design alternatives. By shifting the focus towards performance optimisation, and if minimum compliance ratings are achievable more quickly, this has the potential to encourage a transition towards improved energy ratings and yield potential construction cost savings as a greater range of design improvements can be explored as part of the optimisation process.

3. *SketchuRATE*: an alternative approach to house energy ratings

In response to the aforementioned opportunities for improvement, we have been developing and testing an alternative methodology for conducting house energy ratings. The ultimate goal is to create a seamless integration between NatHERS and a workflow based around BIM, so that house energy ratings can be conducted quickly, accurately and allow for the iterative improvement of thermal performance.

Known as *SketchuRATE*, the "proof of concept" workflow (Figure 2) is based around the creation of a standalone SketchUp model, from which key dimensional, area and volumetric data can be extracted. This initial starting point came about as a quality assurance process while conducting our own house energy ratings, as it allowed measurements to be checked both visually and quantitatively against a simple 3D model (modelled from the original architectural drawings). This in turn lead to the creation of an automated Ruby script that could extract this data directly from the model, which ultimately resulted in the development of a software service that could then convert this data into the .PRO file format used by AccuRate Sustainability.

While the current workflow is based around the use of SketchUp, it should be noted that this data and information could also be derived from BIM applications such as ArchiCAD or Revit, as is suggested in Figure 2. Recently, we have also developed a working prototype that can extract the required information from a Revit model.

Irrespective of the original model source, the data is then converted into a temporary XML file, which is uploaded to the *SketchuRATE* server, parsed, converted and downloaded as an AccuRate

Sustainability data file. At this time, a simplified XML schema has been used, though this can be readily adapted to suit another schema already adopted by industry, such as gbXML and/or ifcXML.

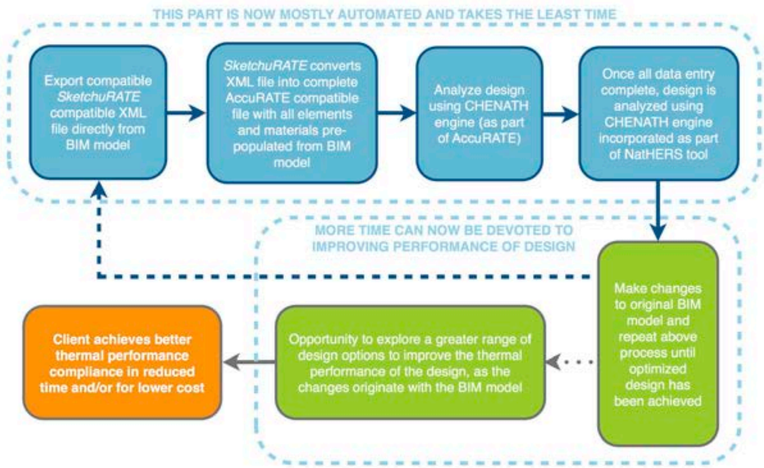

Figure 2: Proposed *SketchuRATE* workflow for House Energy Ratings.

The resultant data file can then be opened in AccuRate Sustainability, and is pre-populated with the following data and information:

- Project name and Design Option ID
- All Zones including volume, floor area, floor height and maximum ceiling height above floor
- All external walls including length, height and azimuth
- All external doors and windows, including name, height, head height, width and horizontal offset
- All internal walls including length, height and adjacent zones
- All floors and ceilings including areas, under the floor and above the ceiling adjacencies
- All roofs including areas, azimuth and pitch

At this time, the remaining data and information still needs to be entered manually in AccuRate Sustainability:

- Construction types and colours
- Zone types and ceiling penetrations
- Horizontal and vertical shading schemes
- Ventilation data

3.1 Results of preliminary trials

Even though the tool is still only at “proof of concept” stage, to date *SketchuRATE* has been trialled in over 50 certified building assessments by an accredited NatHERS assessor. The time taken to carry out an assessment was recorded and compared to times taken using previous assessment methods. The results indicate that the time otherwise required for data-entry of the building geometry was reduced by around 50%. The overall time to complete an assessment remained similar, however more time was dedicated towards exploring multiple opportunities to optimise the final rating. Qualitative feedback from the assessor indicated that the number of data-entry errors were reduced and "de-bugging" of the model was faster due to the visual modelling environment.

These results indicate that the use of *SketchuRATE* can substantially reduce the time taken to enter the information required to conduct a house energy rating. Additionally, it improves the accuracy of data entry and the representation of zones and adjacencies within AccuRate Sustainability.

4. Critique and Analysis

We believe further development and deployment of a software tool like *SketchuRATE* has great potential to streamline the way in which house energy ratings are conducted in Australia. To help guide the development of a useful, robust software tool and associated workflow, the following is an attempt to objectively critique and validate the development approach that has been taken with *SketchuRATE*.

4.1. Why not keep using existing NatHERS software?

There are currently three software tools to choose from when performing NatHERS assessments, each with their own advantages and disadvantages. However, the disadvantage inherent in all of them is the need to manually translate dimensional data and information into the rating software. Since information already exists as part of a typical BIM workflow, it seems to makes sense to leverage this existing data, rather than duplicate unnecessarily.

4.2. Why not use other analysis software that already works with BIM?

There already exists a number of building energy analysis programs that are either already compatible or integrated with BIM workflows. For example, ArchiCAD includes the EcoDesigner plugin that can perform zone-based thermal analysis of a building envelope directly from the ArchiCAD model. There are also tools that can convert BIM data for use with comprehensive analysis programs such as EnergyPlus.

The challenge then lies in trying to produce correlated outputs with the CHENATH engine upon which NatHERS is based. According to NatHERS (2014), any new rating tool/engine must be capable of producing results within a 5 percent margin of those calculated by AccuRate Sustainability across a range of climate zones and sample floor plans.

To date, no thermal analysis program not based on the CHENATH engine has been able to achieve this requirement. Without detailed working knowledge of the CHENATH engine, this is a significant and discouraging hurdle for software developers wishing to explore alternative thermal analysis tools.

4.3. So why not develop a new analysis tool based on the CHENATH engine?

Floyd (2014) estimates that there are less than 2,000 active assessors across Australia; with the number of accredited assessors likely to have dropped further since this time due to the introduction of new qualification and accreditation requirements. Thus, the segment of this target market that would consider switching to a new, fourth rating tool is likely to be too small to justify the significant time and financial resources required to develop and support it. It would therefore seem a more viable approach to integrate with an established software tool based on the CHENATH engine that is already accredited. Since AccuRate Sustainability is the tool that is used to benchmark all other NatHERS software, this would seem the ideal choice.

4.4. Why not demonstrate energy efficiency compliance using an alternative solution pathway?

While it is possible to demonstrate energy efficiency compliance for Class 1 buildings using an alternative solution approach such as the reference building methodology under the NCC, the outputs for compliance generated by this approach cannot be correlated to a NatHERS star rating. While there are critics (Williamson, 2001), it can be argued that “stars” are now embedded in the public and industry consciousness. This consequently makes verification by alternative solution a less attractive proposition for the purposes of NatHERS brand awareness in the housing market.

4.5. Why turn a compliance tool into a design tool?

While its primary function today is as a tool for demonstrating energy efficiency compliance, NatHERS and AccuRate Sustainability were originally conceived as tools that could help to inform (and improve) the design and thermal performance of residential buildings. However, in reality AccuRate Sustainability's unintuitive and form-based user interface makes it difficult to use as a design tool. Consequently, house energy ratings have become the domain of assessors who focus on data entry rather than design optimization.

On the other hand, while more intuitive thermal analysis tools do exist that can give feedback on how a conceptual building design might perform, for the reasons stated above these tools do not satisfy the requirements for demonstrating compliance.

By creating a more streamlined workflow and connection between BIM applications and accredited rating tools such as AccuRate Sustainability, we believe this is the most effective way to optimise and improve a building's thermal performance, while also ensuring analysis outputs can ultimately be used for compliance purposes.

4.5. Are there any competitors to SketchuRATE?

Recently, another software tool has been announced that claims to offer similar functionality to SketchuRATE. Known as FINE4Rate, the product website states it is “a customized BIM application for the NatHERS thermal comfort modelling environment. The software brings the power and speed of BIM to all Energy Assessors that using the AccuRateSustainability software [sic]” (4M, 2016).

FINE4Rate appears to be positioning itself as a standalone application, requiring the user to model or import the project in their proprietary software. It also requires a modified *AccuRate.exe* file to operate. While there appears to be similarities with SketchuRATE, we believe a non-proprietary, software agnostic methodology that integrates with established BIM tools has greater potential to be adopted by industry at large.

5. Where to from here?

While *SketchuRATE* still only exists as a proof of concept/working prototype, we have conceived a project roadmap for the further expansion of the tool’s capabilities, and ultimately commercialisation.

5.1. Automatic transfer of construction material properties

A key focus will be to find a robust way to transfer information about construction materials used in the BIM model into AccuRate Sustainability. While schema such as ifcXML and gbXML have a hierarchy capable of storing the thermal properties of construction materials that can be leveraged within SketchuRATE, it will be necessary to ensure these properties correspondence to those used within AccuRate Sustainability.

The prototype and implementation studies to date have focussed primarily on saving time in relation to the data-entry required to describe the building geometry; this was considered the more challenging and primary hurdle to overcome in the workflow. The need for mapping these geometric elements to construction materials in the Accurate Sustainability database was identified, however is outside of the scope of this study.

As such, it is anticipated this will be a process of mapping the AccuRate Sustainability material database into the required XML schema.

5.2. Automatic generation of shading schemes

Inputting the wing walls, vertical and horizontal shading schemes into an analysis model is perhaps one of the most tedious aspects of data entry when using AccuRate Sustainability. Shading elements such as eaves, overhangs, fences, perpendicular walls and neighbouring buildings must be entered for each individual external wall that is likely to be affected. The CHENATH engine does not possess the ability to resolve the shading impacts of adjacent structures geometrically, such as by using a shading mask calculation.

The advantage of BIM is the relative ease with which these elements can be modelled; elements such as eaves and perpendicular walls are already part of the model's geometry, while neighbouring structures and fences are often modelled for the purposes of planning approval and/or to provide context. It would be extremely beneficial for all third party applications, not just SketchuRATE, if a way can be found to translate these shading geometries directly into the CHENATH engine.

Our experience with manipulating data to be compatible with Accurate Sustainability and the CHENATH engine has indicated that it is likely to be a significant challenge to develop an algorithm/routine for converting BIM geometry into shading inputs compatible with AccuRate Sustainability. However, adding this functionality to *SketchuRATE* (or other similar third-party developed applications) would be a significant enhancement, and will be a focus of future development.

5.3. Automated compliance checking

When demonstrating energy efficiency compliance under the National Construction Code, it is an expectation under the Scheme that assessments follow the *NatHERS Principles for Ratings in Regulation Mode* (NatHERS, 2014). Currently, this is largely dependent upon the assessor interpreting and following the principles as they conduct the house energy rating.

Because of the data and information that can be embedded within the XML file created by *SketchuRATE*, it should be feasible to develop an automated checking process that could parse an XML file prior to conversion, and confirm the validity of inputs against many of these modelling principles. This has the potential to improve house energy ratings and data entry consistency. It could even form the basis of an industry wide quality assurance process, via a vendor-neutral export format, such as nathersXML or similar.

5.4. More informative design and performance feedback

There is strong brand recognition/awareness from both consumers and industry of the star rating system adopted by NatHERS. However, there are still individuals who would seek more meaningful data regarding a building's thermal performance, for which a star rating alone would be insufficient.

Outputs from the CHENATH engine include hourly temperature profiles, along with heating and cooling loads by zone. While some of these outputs can be viewed within AccuRate Sustainability, the interface provided is not conducive to allowing the use of these outputs to inform and improve the building design.

While not directly related to *SketchuRATE*, finding better ways to display and visualise these outputs may also help to improve design outcomes. We are currently exploring these ideas in other research. We see these research opportunities as symbiotic - *SketchuRATE* makes it easier to complete a house energy while more intuitive visualisation tools help us to better understand how a building is performing. Together these tools are more likely to improve the design and thermal performance of buildings.

6. Conclusion

This paper discusses the opportunity that exists to integrate NatHERS energy efficiency compliance with a BIM workflow and methodology. While SketchuRATE is currently a proof of concept/working prototype with limited functionality, there is great potential to streamline the way house energy ratings is conducted. Eliminating the unnecessary duplication of building data helps to improve the accuracy of ratings when demonstrating energy efficiency compliance under the Building Code of Australia. This in turn may also help to reduce the construction costs for energy efficiency compliance.

However, additional investment of time and financial resources to further develop SketchuRATE's capabilities is not without its risks. "Piggy backing" off existing software (and a scheme wholly dependent on the support of federal, state and territory governments) can be a risky proposition; this has previously been evidenced in the fallout from the well-intentioned (but failed) Green Loans scheme.

Despite these uncertainties, the modest "disruption" created by tools such as SketchuRATE will potentially result in a net improvement to the design, quality and cost of dwellings within Australia. When energy efficiency compliance requirements were first introduced into the Building Code of Australia, the intention was to reduce greenhouse gas emissions associated with the operation of buildings. While this net result appears to have been achieved (Ambrose, 2013), the work of house energy rating assessors has unintentionally become an obfuscated process not well understood by the construction industry as a whole, and dominated by laborious, menial data entry.

By more closely linking BIM with NatHERS tools already used for compliance, the focus will shift to iteratively improving a building throughout the design process, instead of just ensuring minimum compliance once a building design has been finalised. Concurrently, the role of a thermal performance assessor will transition from one largely based around data entry and duplication, to providing more comprehensive advice and feedback that can further enhance a building's performance.

Combined with more meaningful and engaging ways to present analysis results, the optimised workflows enabled by a tool such as *SketchuRATE* will help to further reduce greenhouse gas emissions attributed to residential buildings in Australia, and assist in the transition towards a lower carbon economy.

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