Software to save energy
The right app for the right retrofit

While modelling software is used to rate the energy efficiency of new buildings, Richard Keech took it one step further and used computer simulations to assess the value of retrofits at home.

If you're going to spend large amounts of time, money and effort making your home more energy efficient, it would be nice to know in advance which improvements will work best. Computer simulation is often used in commercial situations to help plan and justify sustainability upgrades. However, it's not often used by home owners planning improvements.

In this article I'll describe how I took a high-end building simulation app to model proposed passive improvements to my own house. Hopefully this will convey both the conclusions of the modelling in my case, and more generally about using building simulation software.

Photos and graphics Richard Keech

Richard used software to work out the value of retrofits at his Melbourne home.

My place and my problem

I live in a three-bedroom period home in Melbourne of mixed-mode construction—mostly timber but with the south wall in solid brick. It had a renovation in the late 90s, including a small second storey containing a study and master bedroom. The building's axis is east-west, but it's unable to properly utilise the northern solar aspect due to poor initial design and the neighbour's house. I've already draught proofed, added insulation in the ceiling and under-floor, double glazed and installed good drapes.

So my problem was where to go next in terms of passive improvements to the home. Given my background in IT and my university studies in energy efficiency, I had the interest and opportunity to try my hand at simulating improvements in software. I chose a two-step approach. First I modelled three specific possible improvements with one app to see which was best. Then I used assessment software to let me know how my house stacked up in the star rating stakes.

Apps to help

Many apps are available, ranging from free to very expensive. I'm not going to provide an extensive overview or comparison of what's available, but I will mention the apps I dealt with in my investigations. All the apps mentioned here are for the Windows platform, even though I'd much rather they worked on Linux.

AccuRate. This is the grand daddy of home energy rating packages in Australia, developed by CSIRO and sold by Hearne Software. It is one of a number of packages accepted for official home energy ratings under the federal NatHERS scheme and enjoys widespread use in the area of building research and government assessment and reporting, although it has been the subject of some recent public debate about its limitations.

I used AccuRate to give me a sense of the star rating performance of my house at various stages in my improvement process. This app lacks the fancy 3D user

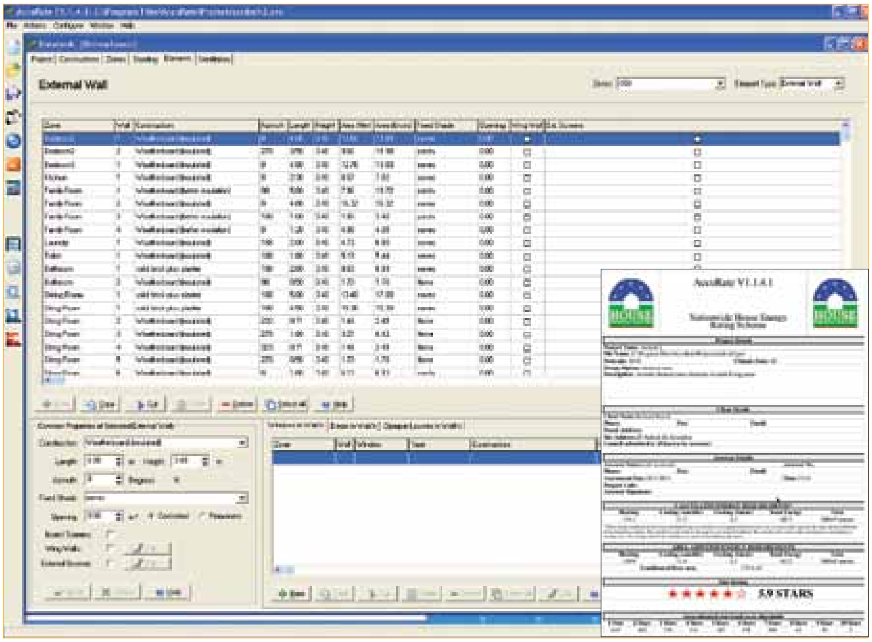


Figure 1. A typical AccuRate display of a home's structural elements. Inset: an AccuRate generated star-rating certificate.

interface of the others. As such, modelling the building is a matter of entering in the geometric relationships between all the rooms. At the time of writing, a new version, called AccuRate Sustainability, has been released with new capabilities, but this is not what I used. A typical AccuRate display of a house's structural elements can be seen in Figure 1.

SketchUp/Energy Plus/Open Studio. SketchUp is a widely used 3D modelling app from Google, available in both free and paid versions. Freely available extensions allow you to do thermal simulation of buildings. In this context, Energy Plus is the thermal simulation software from the US Department of Energy. Open Studio is the SketchUp plugin that allows SketchUp to use Energy Plus. I used this for one university assignment and found it was prone to crash and a bit idiosyncratic.

Virtual Environment (aka VE). VE is a high-end app from IES, which is used more often in large commercial situations where complex simulation of building performance is required. I was required to use this software for one of my university subjects and took advantage of a student licence for use at home. The strong point of VE seems to be its capacity to model very large buildings and complex building systems like air conditioning, or HVAC as architects and engineers prefer to say.

Ecotect. This app is like VE and arguably more user-friendly and less expensive. It's widely used in the building industry but has fewer of the high-end features of VE for simulating complex building systems.

What can the apps do?

Star Ratings. AccuRate is the only one of these apps which is approved to rate a building based on the Australian NatHERS rating scheme. This is the familiar star-rating system for the thermal performance of residential buildings, not to be confused with the NABERS star-rating scheme. NatHERS rates only the building shell, not including things inside or on the building. AccuRate produces the star-rating certificate issued by home energy rating professionals (see inset, Figure 1).

Energy and temperature analysis. The apps all share the ability to perform whole-of-building energy and temperature analysis, and can represent a building at an arbitrary location and with weather input of your choosing based on historical climate data. For example, consider the question: how warm will my house get on a hot day? This is represented in Figure 2, which shows the simulated temperatures for different places in my house on a January day.

Shading. All the apps, except Ac-

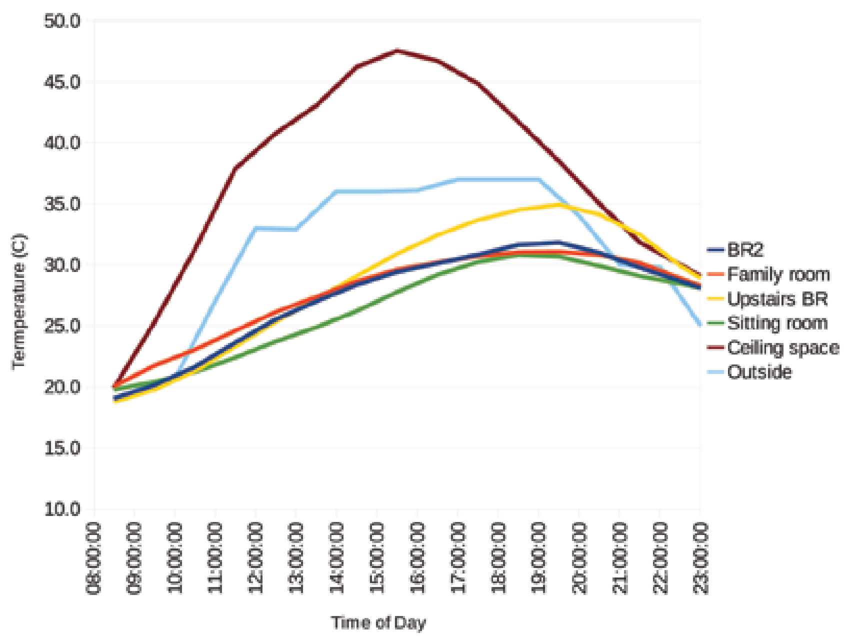


Figure 2. A typical temperature versus time graph for different locations in the home.

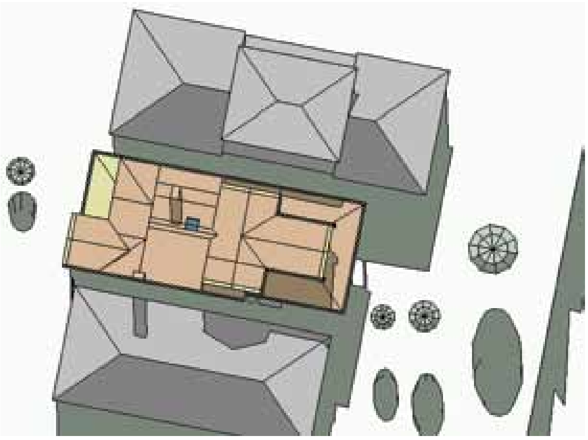


Figure 3. Simulated shading diagram for June 21 at midday.

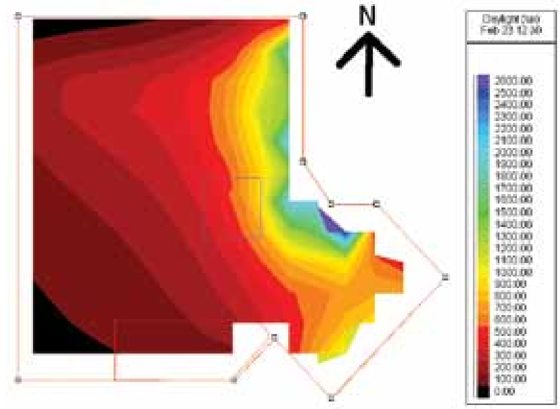


Figure 4. The daylighting effect of adding a clerestory window on one of the north-facing walls.

cuRate, can also give graphical shading analysis, meaning they can show what will be shaded at certain times on certain dates. For example, Figure 3 shows simulated shading at midday on June 21. This shows how the winter solar gain is limited due to overshadowing.

Daylighting. VE and Ecotect can tell you how good the natural light inside the building will be. Figure 4 shows the effect of adding a clerestory window on one of the north-facing walls.

My analysis

In my case I used VE to analyse the relative merits of three possible improvement measures: extra insulation, thermal mass and cool roof coating. I started by modelling the entire structure in 3D and the results are shown in Figure 5. This was far more time consuming but more detailed than the type of house characterisation involved in AccuRate. I was able to specify 'internal gains' such as heat from appliances and people. Also added were material types and surfaces and adjacent objects like buildings and trees. I could have modelled an active heating and air conditioning system, but chose instead to do free-running analysis, meaning I looked at the performance in the absence of any active heating or cooling. The one active element I did define was a regime for opening and closing of windows based on temperature, as occupants would tend to do naturally when it's hot.

Location and weather

I defined the model as having the appropriate latitude and longitude and applied a specific weather profile based on Melbourne airport. The weather profile uses what's called a typical meteorological year which is a derived from a patchwork collection of weather records to arrive at a year in which each month is about average.

I produced numerous variations on my house model. One represented a baseline, showing how the house is now. Others represented different combinations of the proposed building changes. I simulated each house model's performance for one entire year and then compared how comfortable my changed house was relative to the baseline model.

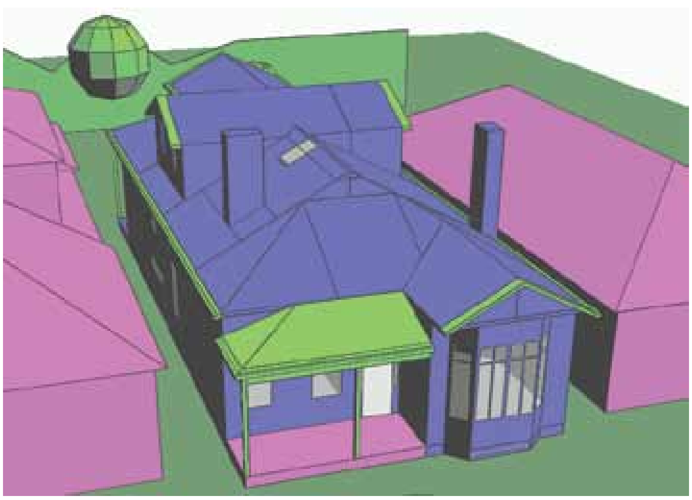


Figure 5. The house modelled in 3D.

My results

I considered the free-running performance by using histograms of temperature in each room across all 8760 hours of the year. For example, Figure 6 shows the before (blue) and after (red) results for the family room. The blue data shows a broad spread of temperatures. The number of samples at lower temperatures shows that heating load is dominant and that the time spent in the comfort range of 20°C to 26°C is not sufficient.

In comparison, the red data represents the same room under the same weather conditions. The difference was the addition of wall insulation, internal thermal mass and a cool roof. The results are markedly different. We're still not talking Passive Haus performance, as shown by the number of hours where the temperature was less than 20°C. But it's a big improvement.

Applying this approach to the whole house in all combinations of the three proposed improvements resulted in the data in Figure 7. The main take-away messages of this for me, in my climate, are:

- when applied on a bare-metal roof, cool roof surface coatings can actually make things worse in winter, and increase the overall energy use
- thermal mass makes a big difference in summer, however, the baseline number of uncomfortable hours in summer is much less than in winter
- insulation is the most important single measure
- passive measures are never going to give me adequate winter performance by themselves, but they'll reduce the heating demand enormously
- passive measures can remove the need for air conditioning in summer.

Building ratings

The second part of my assessment was to rate the house using AccuRate. I modelled the house in three variants including before applying any improvements (baseline), as it is now (improved 1), and with some further improvements (improved 2). The baseline case resulted in a paltry 1.1 Stars. With the addition of draught proofing, underfloor insulation, extra ceiling insulation and secondary glazing, the house rates as 2.9 Stars, which corresponds to a 47% reduction in space-conditioning energy requirements.

The third case models the hypothetical addition of insulated walls, high-performance glazing, removal of unused chimneys and an insulated door. This would get the rating to 5.9 Stars, or a 77% energy reduction from the baseline case.

Not so cool roof

The most surprising finding of the simulations was that a cool roof coating, by itself, would probably increase the year-round energy requirements in my case. This is because the existing bare-metal roof, having low natural emissivity, would lose slightly less heat in winter due to radiation than a cool roof material. Aside from that, this study supports my original gut feeling that the most important next step is to get the walls insulated. On the star rating side, I was surprised just how hard it is to get an old house to 6 Stars and beyond in the absence of good winter solar gain.

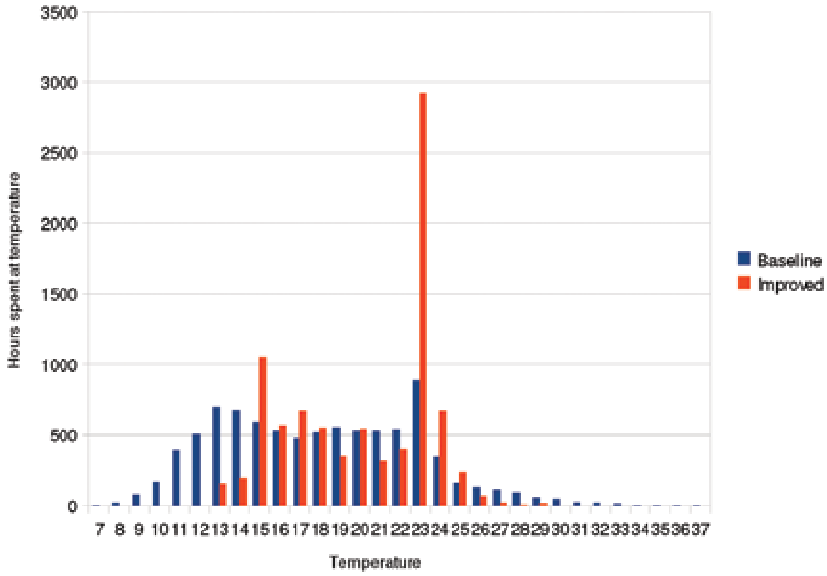
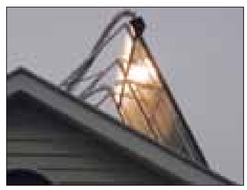


Figure 6. The blue baseline data shows the broad spread of temperature variations before modifications while the red data shows how much better the room will perform with added insulation, thermal mass and a cool roof coating.

References and links

AccuRate: www.hearne.com.au/products/accurate/edition/accurate
Energy Plus and Open Studio: http://apps1.eere.energy.gov/buildings/energyplus
Virtual Environment: www.iesve.com
Ecotect: http://autodesk.com/ecotect
Your Home: www.yourhome.gov.au
Design For Climate: www.designingforclimate.com.au
NatHERS: www.nathers.gov.au

See Richard's article *Super-efficient hot water* in *ReNew 115*.



Thermal mass	Cool roof	Insulation	Winter % comfort improvement	Summer % comfort improvement	Annual % comfort improvement
no	no	no	0	0	0
no	no	yes	32.7	23.5	32.2
no	yes	no	-14.6	20.7	-4.4
no	yes	yes	27.0	42.2	27.9
yes	no	no	7.5	81	11.5
yes	no	yes	33.6	87.6	36.5
yes	yes	no	2.6	82.7	7.0
yes	yes	yes	28.0	89.5	31.3

Figure 7. Improvements in performance for the different combinations of proposed energy efficiency improvements.