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RESEARCH PRODUCT & DEVELOPMENT
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A DESIGNER'S BRIEF GUIDE TO ENERGY EFFICIENCY IN BUILDINGS

INTRODUCTION

Over the last few years building approval authorities in Australia have paid a lot more attention to the energy efficiency of proposed new dwellings. This has been part of a more general concern to reduce the generation of greenhouse gases, which are the prime contributors to global warming and weather changes. As a conscientious manufacturer of building products, James Hardie wholly supports these initiatives.

While space heating and cooling is not necessarily the biggest contributor to the overall energy use of a typical family house, it has been the target of the greatest effort through house energy rating schemes such as the Energy Smart Homes Policy in New South Wales. One of the reasons for this is that improvement in the building fabric benefits the householder, not only in lower energy use, but also usually in much improved comfort.

Most recently, energy efficiency provisions have been introduced into the Building Code of Australia (BCA) [1]. Different states have adopted different levels of stringency. In Victoria, where the majority of the energy is spent on heating of living spaces, the commitment is to very high levels of performance, with an eventual requirement that all new dwellings will need to achieve five-star ratings using the existing rating software. New South Wales has still not finalised the exact requirements, but has committed to the adoption of a comprehensive sustainability rating scheme known as BASIX, which will have requirements over and above the present NatHERS star ratings.

With these increased requirements, it has become obvious that compliance will not be easy to achieve in some climates. The purpose of this technical bulletin is to help improve the understanding of how prudent building design contributes to good projected energy performance.

FUNDAMENTALS

The improved thermal performance of the building fabric is intended to produce two related effects: (a) improved comfort of the inhabitants, with (b) lower overall energy use for artificial heating and cooling. In the design of dwellings, one can take either or both of the following alternative approaches to achieving these ends:

[1] Climate Responsive Design

The first of these approaches might be called 'climate responsive' design, and is based on the assumption that energy use is minimised if one can, as far as possible, avoid switching on artificial heating and cooling. An example of this approach in cooler climates is commonly referred to as passive solar design, which seeks to utilise the free heating available from the sun. Another example is the enhanced natural ventilation of buildings in the warm humid tropics, whereby outside fresh air is drawn into the building by the design geometry.

[2] Energy Conserving Design

The second approach is usually referred to as 'energy conserving' design. This approach is different in one important respect. It assumes that artificial heating or cooling is installed in the dwelling, and therefore is likely to be switched on whenever conditions are uncomfortable. Energy conserving design therefore tries to minimise how much of this artificial heating or cooling is wasted by being lost through the building fabric.

In most parts of Australia, we enjoy relatively temperate climates, where both these approaches can be applicable. The 60L building[2] completed at the end of 2002 and CH2 building[3] currently being constructed, both in the Melbourne CBD, are excellent examples of where both these principles were integrated to produce office buildings that use less than half of the energy used by similar buildings of more conventional design.

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Arguably, good climate responsive design can achieve by far the greater overall energy savings in most of these climates. However, some of the principles of climate responsive design are more difficult to implement – such as when a site is poorly oriented for solar access. In addition, the climate responsive performance of the building is very much dependent on the behaviour and environmental goodwill of the occupants.

House energy rating schemes are not equally successful in assessing these two different design approaches. Climate responsive design is best assessed by looking at all the factors that contribute to the comfort of occupants, in ways that best reflect their actual occupancy patterns and lifestyle. Understandably, this can be quite difficult – mainly because everybody's lifestyle is different. Legislated rating schemes therefore take a more conservative approach.

Existing house energy rating software such as NatHERS and FirstRate do simulate the way a proposed dwelling provides thermal comfort in a given climate. However, they take a worst-case scenario, which assumes that artificial heating and cooling are used whenever predicted indoor conditions fall outside a defined range of comfortable temperatures. In this respect, house energy rating software simply compares the relative potential energy conservation performance of houses to each other, and may give little indication of actual energy use by particular occupants who may be trying their best to adopt a more ‘green’ lifestyle.

At present, there is no available rating scheme based on comfort considerations alone. Therefore, for all intents and purposes, house energy rating schemes tend to reward energy conserving design. To reliably achieve good ratings under these schemes, it is therefore important to understand the factors that contribute most effectively to energy conservation.

GOOD DESIGN FOR ENERGY CONSERVATION

In the more demanding climates, it is very difficult to obtain the highest star ratings under existing house energy rating schemes, unless attention is paid to most aspects of the dwelling design. It is almost impossible to overcome poor overall design by improving the performance of a single element such as the insulation levels of walls or roofs. The following checklist sets out the main factors to which attention should be paid.

[1] Reducing the external “loads”

The term may sound excessively technical, but it boils down to protecting the dwelling from those climate factors that increase heat losses in the winter or cause overheating in the summer, namely:

- Provide shelter from cold winds, which mainly involves site design including landscaping, but also such things as being able to enter the house through an airlock space such as the lobby or a laundry.
- Orient the building so as to avoid excess solar gain through glazing.
- Provide shading in summer, especially for glass surfaces.
- Generally use light colours, especially for the roof, to reflect rather than absorb solar heat.

[2] Use “free heating”

Passive solar design is achieved by:

- Good orientation of glazing. A generally northern orientation is advantageous. Many standard designs can often be significantly improved by good siting and attention to window placement.
- Appropriate thermal mass. Significant surface areas of appropriate materials are needed to absorb the solar gain during the day, and return that heat to the living space in the evenings.

[3] Use “free cooling”

This is achieved by good ventilation design:

- Incorporate cross ventilation.
- Provide securable openings that may be left open at night.
- Use well designed windows to capture prevailing breezes.
- Employ appropriate thermal mass. This is often ignored, but is equally important if the dwelling is to remain cool as long as possible into a hot day.

[4] Compact building forms

Historically, larger houses have found it easier to achieve higher star ratings, simply because they have a lower ratio of external surface to plan area. This has tended to obscure the fact that in spite of their better star ratings, larger houses on the whole would still be using more energy for heating and cooling than smaller houses. The soon to be introduced newer versions of the energy rating software should remedy this anomaly.

However, it will still be the case that energy conserving design as assessed by the rating software is generally best served by compact rather than extended building forms. This is a contentious issue in the architectural

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design community, because it favours the more common project homes over individual designs that may be making a greater effort to be climate responsive in their particular locations.

[5] Appropriate insulation

Insulation reduces the rate of heat flow through the external elements of the building. Its value is directly proportional to the area of the building fabric to which it is applied.

- High standards of insulation are most effective in the roof/ceiling system.
- There is a marginal rate of return for improved insulation. In each climate zone there is an optimum level of added insulation for each of the major elements of construction, going beyond which little or no additional benefit is obtained.
- In warmer climate zones it is even possible to over-insulate, where the insulation actually prevents the dwelling from cooling down quickly enough in the evenings.
- Attention should be paid to the weakest element, invariably the glazing. Double glazing effectively halves the heat transmission of a window. Good quality window treatments, including external “block-out” style operable shutters, can achieve the same or better performance.

The relative impacts of insulation are illustrated in the comparative study below. For example, it shows that the roof space is the most effective part of the building to insulate.

DATA STUDY 1: HEATING ENERGY IN HOMES

A simple simulation can show the impact of improving the major construction elements of a typical single-storey house in Climate Zone 6. This simulation compares only the required heating capacity, i.e. the size of the heating plant needed to be installed in order to maintain thermal comfort on a cold night. It does not predict the overall reduction in predicted overall heating load as given by the rating software. Figure 1 shows the contribution of individual building elements to improved winter heating performance.

As can be seen, the biggest impact is from insulating the roof and ceiling. If all elements are attended to, including substitution of a concrete slab on ground for a suspended, uncarpeted timber floor, the overall heating capacity required is reduced to less than 30% of that for the uninsulated house.

It is also clear that little additional capacity remains to improve overall performance by increasing the insulation value of the walls. The most potential improvement remaining is the reduction of glazed areas, or the substitution of double-glazing.

Figure 2 represents the same data in a bar chart format. In this chart it can be seen that, for our typical cold climate example house, up to 33% of the heating on a cold night may be saved by insulating the roof space; an

Figure 1 - Contribution to heat loss

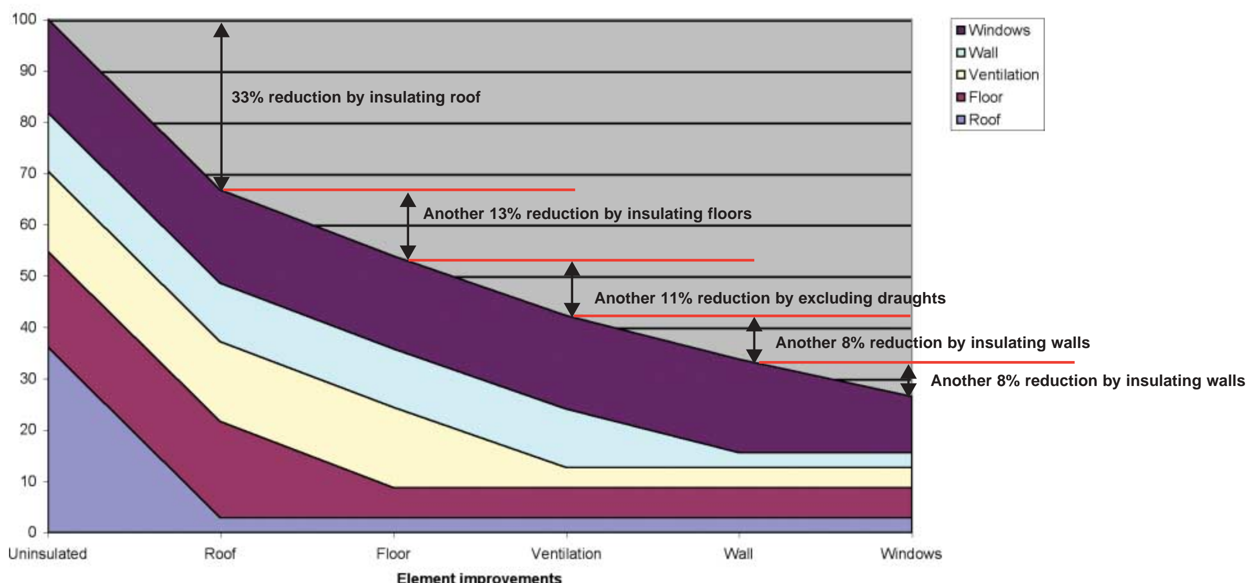

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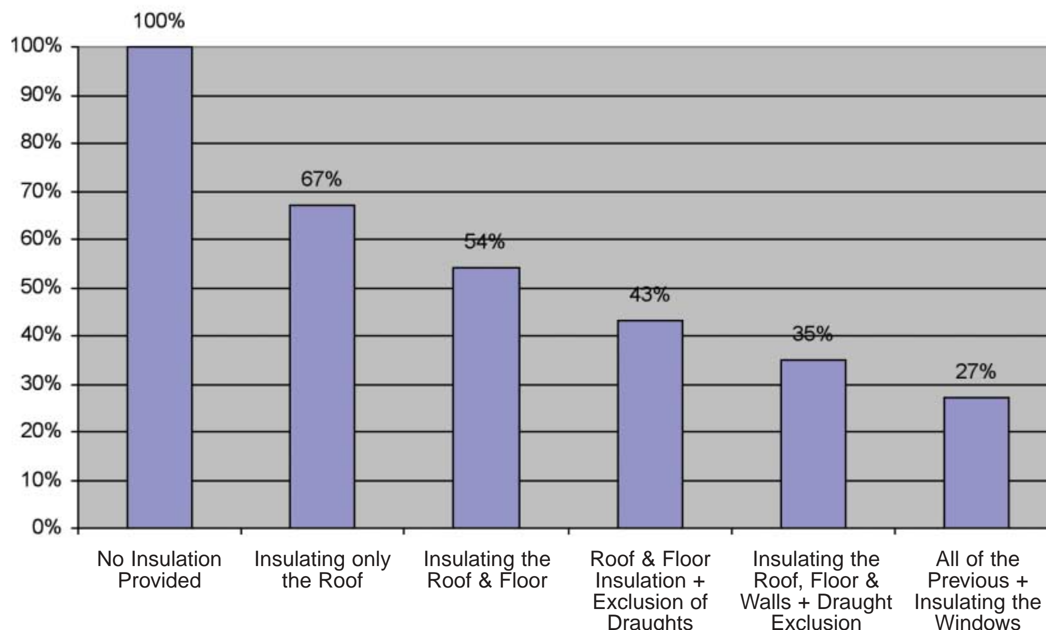
Figure 2 - Progressive Contribution by Insulation to Savings in Heating



additional 13% saving is available by improving the floor; another 11% by excluding draughts and unwanted ventilation; a further 8% by insulating the wall; and a final 8% extra by providing better glazing or window coverings.

FACTORS THAT REDUCE HOUSE ENERGY RATINGS

More than six years of experience with house energy ratings in Victoria, the ACT and New South Wales has confirmed the factors that most detract from good energy ratings. A study undertaken for SEDA New South Wales[4], comparing typical project homes with individually designed dwellings dramatically illustrated these findings:

[1] Excessive glazing area

This is the single greatest problem. Typical single glazing loses or gains heat at least ten times as quickly as a typically insulated wall. This problem is usually most obvious in individually designed dwellings where there tends to be an emphasis on open space, natural light and the exploitation of views. On the whole, project homes have more modest glazing ratios.

Advanced glazing systems have some potential to overcome high glazing ratios where the window areas are justified by other design factors such as views. The cost of such glazing systems can become a limiting factor, and ultimately the best remedy is to be more discriminating about window placements, rather than using larger window areas.

[2] Poor orientation

Poor orientation of large glazing areas can contribute to severe summer overheating. This typically occurs where views are available to the west and southwest.

Good design again reduces such glazing areas, and compensates by more careful placement of windows to capture the most dramatic outlook.

[3] Excessive wall areas

Accompanied usually by excessive glazing area, excessive wall areas can dramatically lower achieved star ratings.

Again, this is more often a characteristic of individually designed homes. To an extent this penalty can be an unfortunate by-product of the inability of the ratings software to reward aspects of climate responsive design, because such houses are often designed to respond more carefully to their sites and microclimates. However, the software does accurately reflect what might happen where such houses are retrofitted with more heating and air-conditioning by future owners.

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[4] Absence of thermal mass

Placing little or no thermal mass into the building makes it very difficult to achieve the highest star ratings. The complete absence of surface areas of appropriate thermal storage material tends to produce houses that have bigger temperature variations both in summer and winter. Because the ratings software has standardised occupancy scenarios, it treats these variations as requiring more cooling or heating. Such dwellings therefore tend to be penalised with lower star ratings.

In conclusion: where insulation values of individual building elements are already reasonable, it is very difficult to overcome the four design problems discussed above by further improving the performance of an individual element - such as increasing the thermal resistance of the walls.

A much more productive approach is always to examine the underlying problems in greater detail.

DATA STUDY 2: DESIGN VARIABLES IN HOMES

A study[4] undertaken for SEDA New South Wales compared the ratings performance of a sample of individually designed dwellings with those of typical project homes on the New South Wales market.

A number of indices can be used to describe the general characteristics of the house designs. These indices are:

- The ratio of wall area to floor area,
- The ratio of window area to floor area, and
- The ratio of total external surface area (including roof) compared to floor area.

Figure 3 illustrates the ratings achieved against these design indices. Remembering that the minimum requirement in New South Wales at the time was a three and a half star rating, it is notable that all the project homes achieved compliance, while few individually designed dwellings in the sample did so.

The two most distinguishing factors that could be identified were that project homes have consistently more modest glazing ratios (see Figure 4), and except for the attached dwellings included in the individually designed sample, more modest wall area ratios.

Figure 3 - Test dwellings comparison with Project Homes for Key Indicies

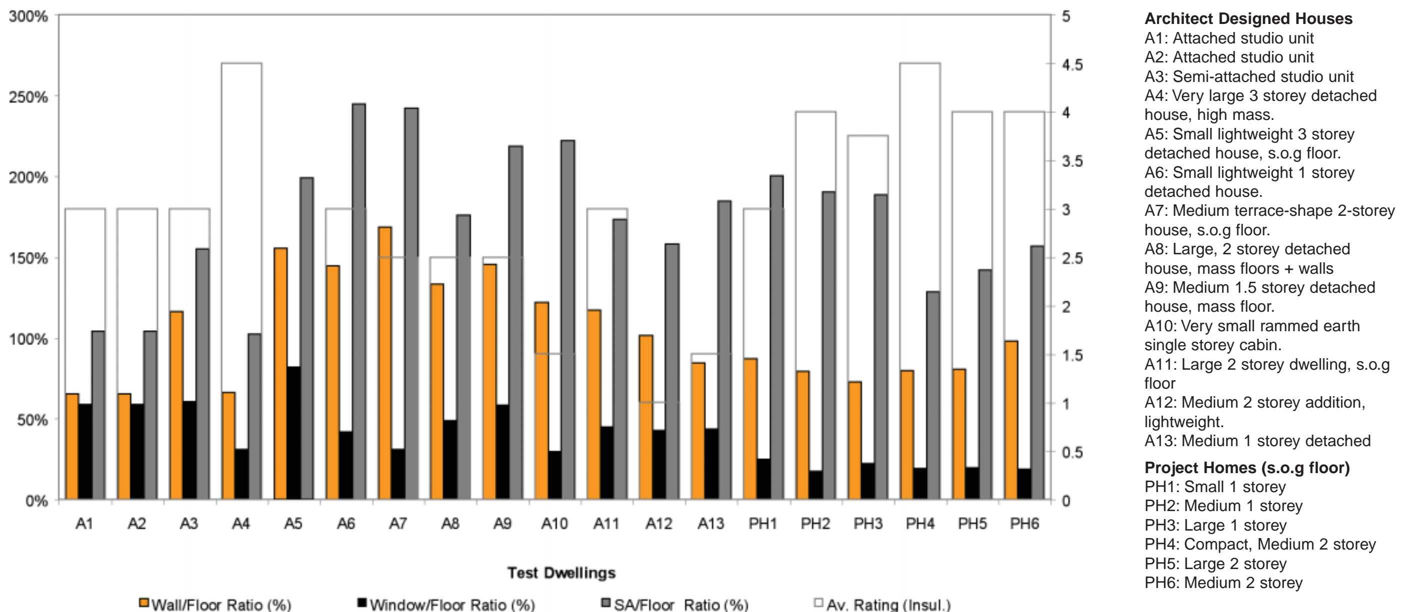

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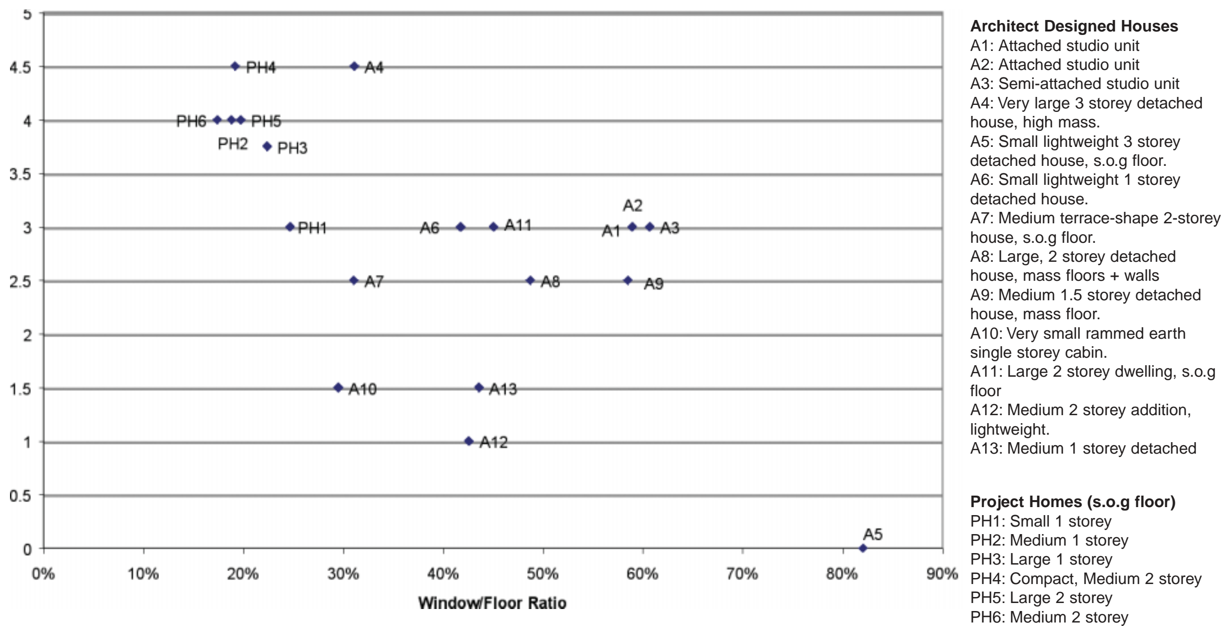
Figure 4 - Window/Floor Ration against Star Rating

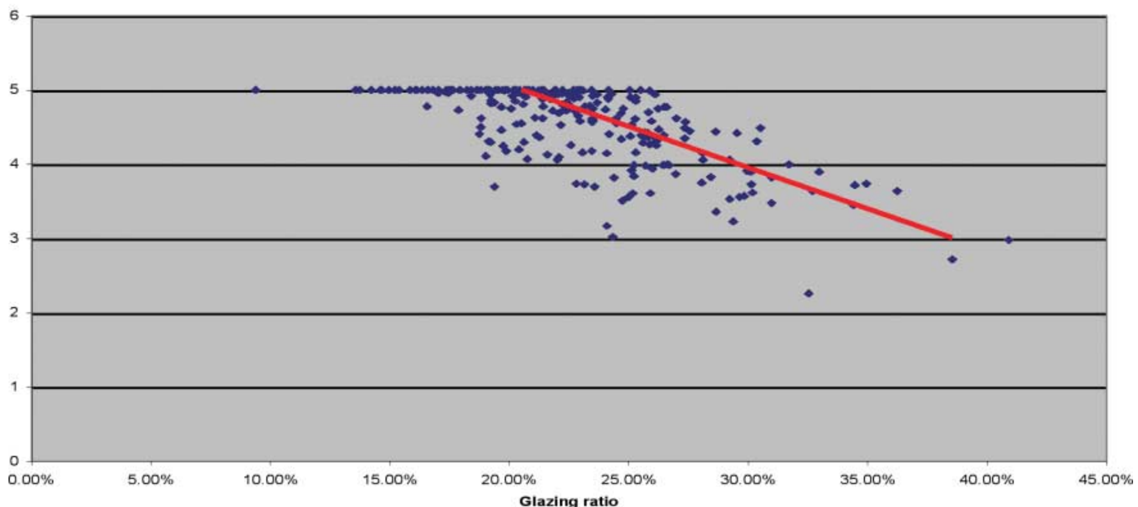


DATA STUDY 3: GLAZING RATIOS

The impact of the total area and distribution of glazing on the energy rating of an individual house can only be predicted by carrying out an individual rating simulation. This impact can be quite variable. However, a general trend can be easily identified if a sufficient number of houses are compared. Figure 5 is taken from an unpublished study of 240 typical houses on the Victorian and NSW market. The sample represents a large variety of house sizes and construction methods, of single and double storey. General orientations and the distribution of glazing orientations vary widely. For the purpose of this comparison, all houses were simulated with concrete slab on ground floors and conventional eaves. Appropriate insulation levels for Climate Zone 6 are assumed.

The study shows clearly that star ratings are directly related to the overall proportion of glazing. In these houses, none achieved a five-star rating if its glazing ratio was in excess of approximately 26% of its floor area. Even with modest glazing ratios, the star ratings were quite sensitive to the distribution of orientations of the glazing.

Figure 5 - Star ratings and glazing ratios



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CONCLUSION

James Hardie is committed to the principles of ecologically sustainable development (ESD) and hence hopes that this bulletin may have added to the knowledge base of our Australian and international designers of housing, whether residential or commercial.

Furthermore James Hardie encourages designers to keep striving towards new ideas and methodologies to increase the energy efficiency in buildings and thereby reduce the impact on the earth's environment.

Whilst the current crop of house energy evaluation schemes may not be perfect, in that they may not duly reward climate responsive design and the environmental goodwill of the occupants, they remain an important step in the right direction for us to improve our ecological citizenship of this planet.

REFERENCES

This bulletin has been prepared from information and text provided by Steve King of SOLARCH at the University of New South Wales. Simulation studies referred to have been undertaken specifically for this publication, or as part of sensitivity studies for proposed deemed to satisfy conditions for the BCA.

The following information or published documents are referenced in the text:

[1] Building Code of Australia (BCA), Standards Australia publication, 2004.
[2] 60L Building website: www.60Lgreenbuilding.com
[3] "CH2: This proposed new building by Melbourne City Council has the potential to be a beacon of environmental innovation", Lindsay Johnson, Architectural Review, AR 084, Winter 2003.
[4] King S. and Veale J. "Energy Rating Performance of Architect Designed Houses" in proceedings of ISES 2001 SOLAR WORLD CONGRESS Adelaide, 25-30 November 2001

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