SUSTAINABLE CONSTRUCTION FOR THE FUTURE – THE ROLE OF GOVERNMENT IN ENERGY EFFICIENCY AND SUSTAINABILITY IN BUILDINGS

Full Paper

BENCHMARKING SUSTAINABLE RESIDENTIAL DWELLINGS

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ABSTRACT

This paper will summarise the findings from a study that explored the link between dwelling design, or type, and energy efficiencies in sub-tropical climates. An increasing number of government and private sector development companies are initiating projects that aim to deliver enhanced environmental outcomes at both sub-divisional and dwelling levels. The study used AccuRate, a new thermal modelling tool developed by CSIRO that responds to the need to improve ventilation modelling. The study found that dwellings developed in conjunction with the Departments of Housing and Public Works have set the benchmark. It provides a snapshot of the energy efficiency of a range of dwelling types found in recent subdivisions. However, the trend toward increasing urban densities may reduce the likelihood that cooling breezes will be available to cool dwellings. The findings are relevant to regulators, designers and industry in all states interested in reducing the energy used to cool dwellings in summer.

Keywords: Sustainable, ventilation, energy-efficiency, density, benchmarking

Benchmarking Sustainable Residential Dwellings

Australia's pattern of residential development is resulting in urban sprawl and highlights the need for development to be more sustainable to avoid unnecessary demand on natural resources and to safeguard the environment for future generations. This becomes more apparent when we note that:

- Australia's per capita consumption of space (floor space, private and open space) energy and water rank among the highest in the world and continue to increase
- Australia's per capita waste is among the world's highest
- Australia's metropolitan planning and development strategies deliver poor environmental outcomes in energy production and consumption and CO_2 emissions, with rapid growth in transportation and resistance to distributed or solar energy in suburbs.

Queensland is currently Australia's fastest growing state, and:

- The estimated population of the region in 2004 was 2.65 million
- This is projected to increase to 5.3 million by 2026
- The population increase is an average of around 50,000 each year.

Much of the population growth is in SEQ region, which encompasses eighteen local governments, extending from Brisbane north to Noosa, south to the New South Wales border and west to Toowoomba. This region has:

- Experienced sustained population growth since the 1980s
- Is growing at an average of 55,000 persons each year
- Requires some 550,000 new dwellings to be constructed between 2004 and 2026.

RESIDENTIAL ENERGY USE

The use of energy in the dwelling is the largest source of greenhouse gas emissions from Australian households. The average household's energy use is responsible for about eight tonnes of carbon dioxide (CO2), the main greenhouse gas, per year (Reardon, 2001). Figure 1 shows the typical Australian breakdown of energy consumption within the dwelling and shows that space heating/cooling and water heating dominates the energy use profile. Reducing a dwellings need for such energy or seeking alternative renewable means of energy for these areas will greatly reduce Australia's overall environmental impact and greenhouse gas production.

Figure 1 Australian household energy use

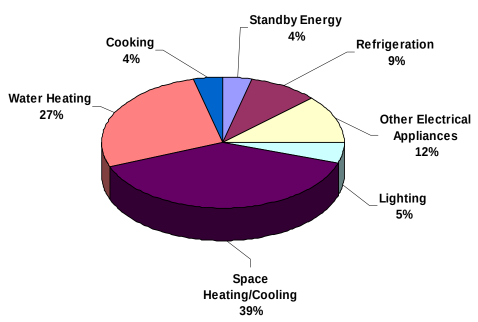
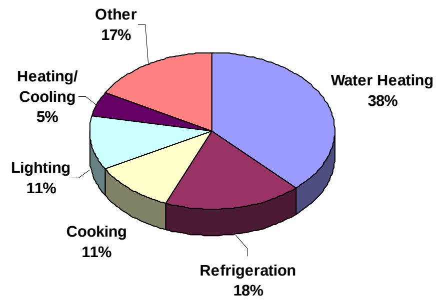


Figure 2 Queensland household energy use



Energy use in Queensland is quite different from the pattern for the rest of Australia. Figure 2 shows that in Queensland, the single biggest consumer of energy in the dwelling is hot water heating (Queensland Conservation Council 2004). Figure 2 also shows that heating and cooling energy accounts for only five per cent of the total, compared with 39 per cent as the Australian average (Figure 1). This difference is due to the temperate climate of Brisbane where the need for conditioned spaces is minimal. While the percentage of energy used to cool dwellings is small compared to the southern states, savings in this area are still important. In any event, this percentage is set to increase as Queenslanders install airconditioning at an increasing rate.

Figure 3 Air-conditioned households in Queensland

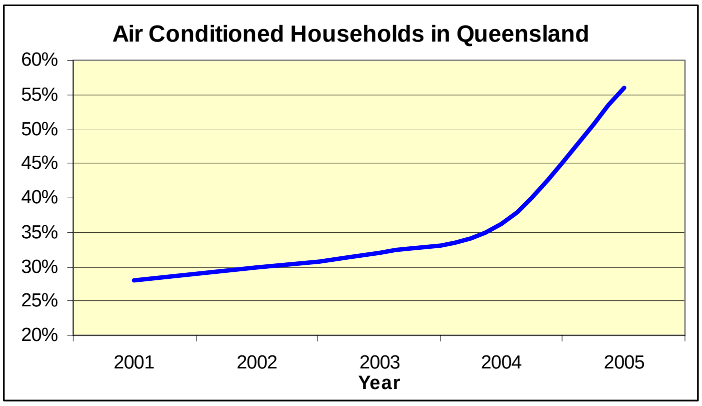


Figure 3 shows that in 2001, around 28 per cent of dwellings were airconditioned. By 2004, this figure had increased to 36 per cent and is expected to continue to increase to 56 per cent in 2005 (Mickel 2004).

This paper will summarise the findings from a study that explored the link between dwelling design, or type, and energy efficiencies in sub-tropical climates. The findings are particularly relevant to regulators, designers and industry in the warmer climate states of Queensland, Western Australian and the Northern Territory. The findings are also relevant to the cooler states as all dwellings have the potential to use energy to cool dwellings in summer.

THE CASE STUDY DWELLINGS

In September 2003, Queensland adopted the Building Code of Australia (BCA) energy efficiency provisions, which address house construction specifically, as this influences the amount of energy needed for heating and cooling. These provisions include requirements for new housing to achieve a minimum energy performance of 3.5 stars[1]. This minimum rating currently under review and is likely to increase to 5 stars (DLGP, 2004).

The study examined a range of dwellings types that commonly occur in new developments to provide a snapshot of the range of energy efficiencies in the aftermath of the introduction of these energy provisions. There are two broad categories, those designed for traditional ‘cut and fill’ lots and those designed for sloping lots;

- Slab on ground construction (Figure 4 to

[1] The present star band settings cover a range of 1 to 5 stars with 5 being the best and 1 representing the worst, or highest level of energy consumption

Figure 7)
- Elevated and pre-fabricated construction (to Figure 11).

A growing number of government and private sector bodies are initiating projects that aim to deliver enhanced environmental outcomes rather than continuing with a ‘business as usual’ approach. At the sub-divisional level, some developers engage sustainable principles in sub-divisional layouts and in construction, providing environmental plans and site analysis recommending layout for a home suited to each site (Ambrose, Mead et al., 2004)

At the dwelling design level, this approach to dwelling design is exemplified in dwellings developed in conjunction with the Departments of Housing and Public Works. These dwellings include Research House, Rockhampton and the Smart Homes at Springfield. These dwellings were selected for examination because they address the range of sub-divisional issues developers and designers contend with in SEQ, such as designing to address increasingly percentage of steep slopes and of small sites, as well as the complexities of designing to exclude excessive solar access and optimise natural ventilation (QDPW, 2003).

Figure 4 Case study 1 Research House, 220m², single storey blockwork on slab, metal roof,4 bedroom, 2 pedestal

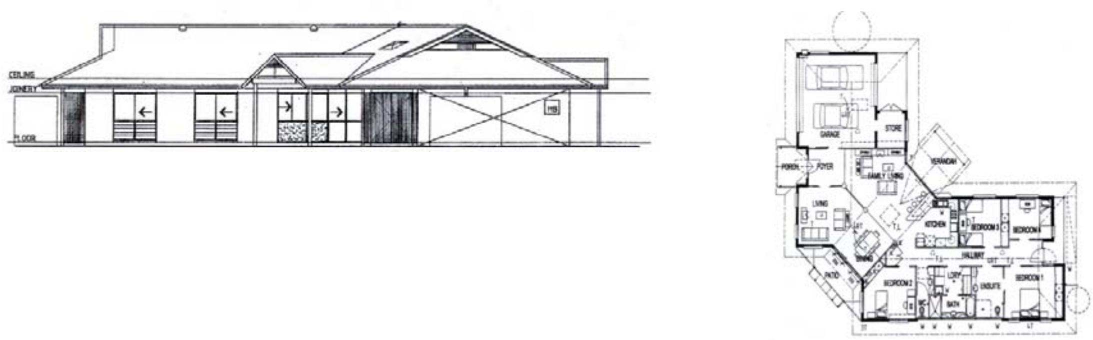


Figure 5 Case study 2 – 194m², brick veneer on slab, tiled roof, 4 bedroom, 2 pedestal

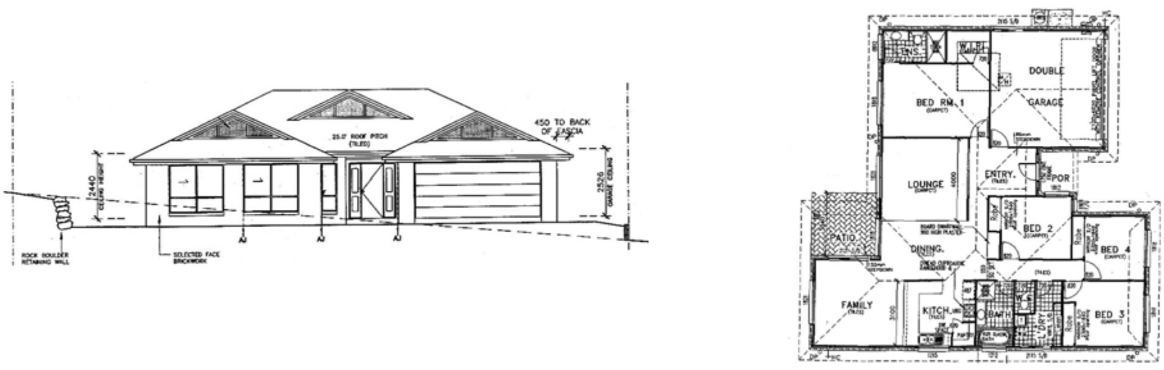


Figure 6 Case study 3 - 104m², brick veneer on slab, metal roof, no eaves on long axis, 3 bedroom, I pedestal

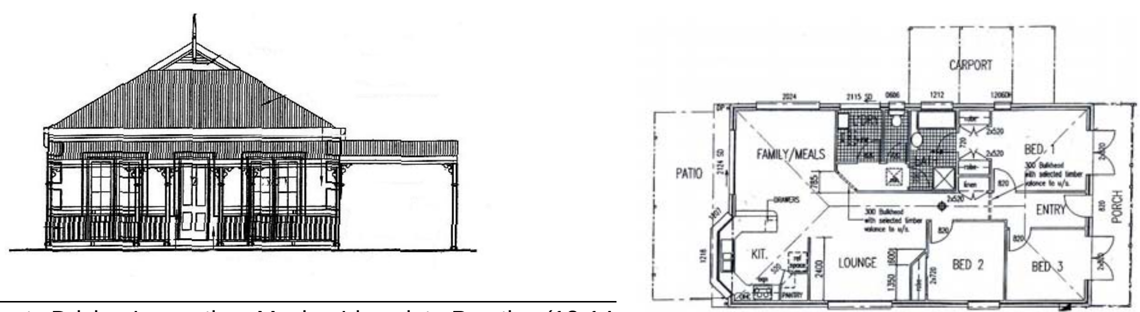


Figure 7 Case study 4 – 287m², two storey brick veneer on slab, metal roof, 4 bedroom, 3 pedestal

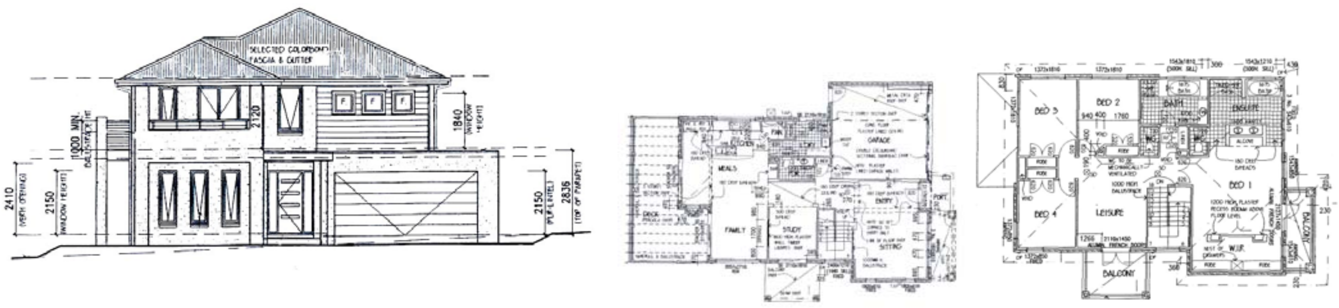


Figure 8 Case study 5 –Greensmart Home, 150m²single storey, elevated, clad, metal clad, 3 bedroom 2 pedestal

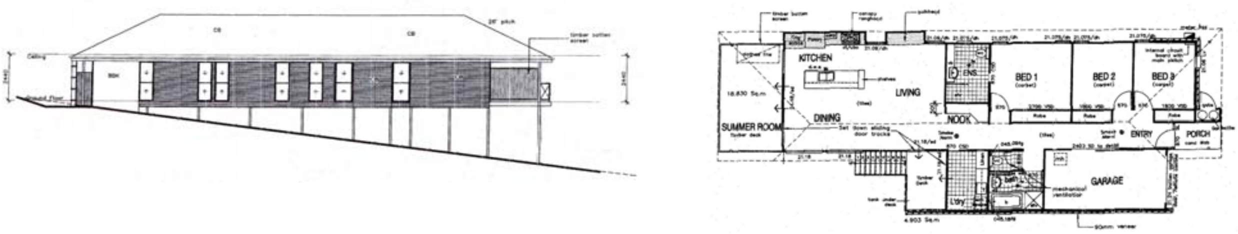
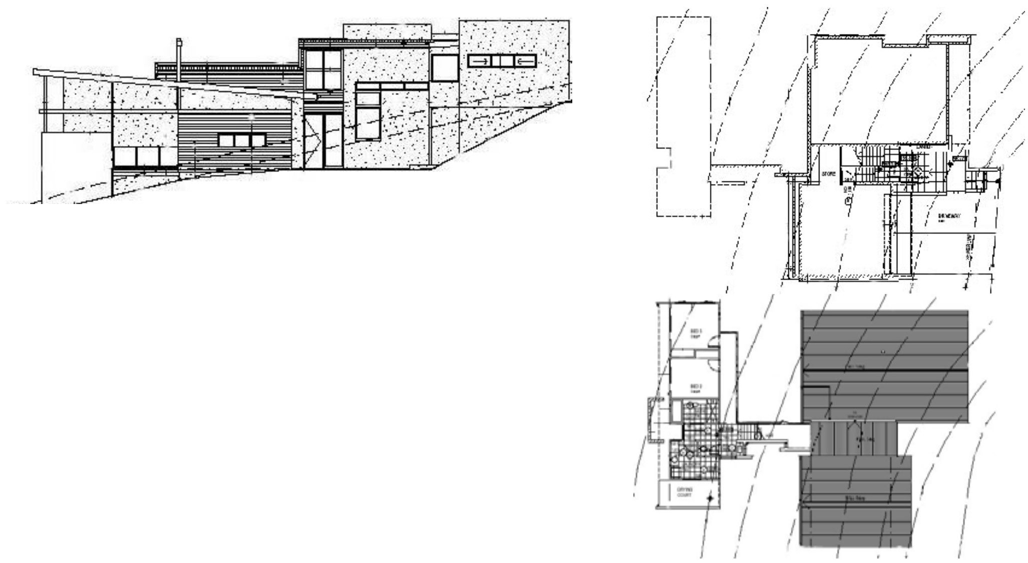


Figure 9 Case study 6 – 263m², split level, clad, metal roof, 3 bedroom, 2 pedestal



10 Case study 7 – prefabricated, 100m²single storey elevated, clad, 3 bedroom, 1 pedestal

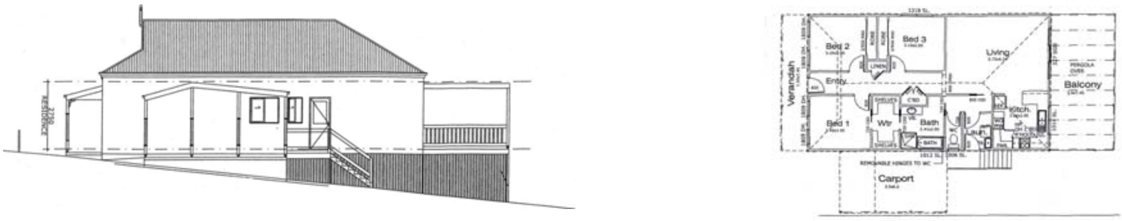
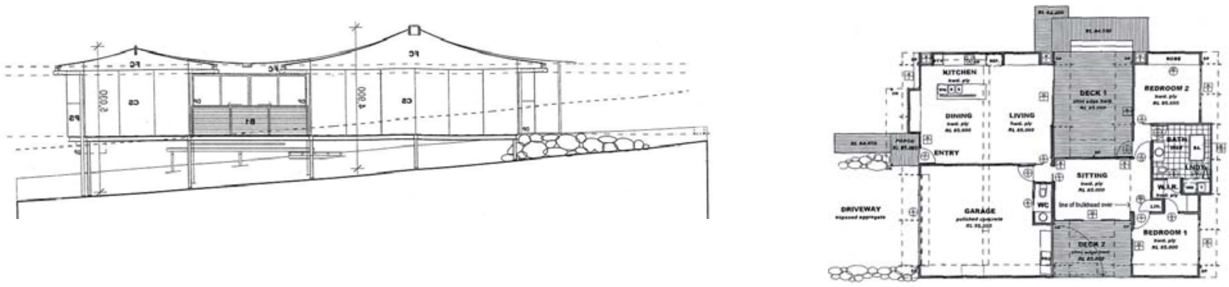


Figure 11 Case study 8 - 140m² single storey elevated, prefab, lightweight clad, metal roof, 2 bedroom, 1 pedestal



Further details of these dwellings can be obtained from the Industry Report (Miller and Ambrose, 2005). available online at http://www.construction-innovation.info/images/pdfs/SusSubdivsRTI_final.pdf.

ASSESSING ENERGY EFFICIENCY

Dwelling energy efficiency is expressed on a scale of 1 to 5 stars, with 5 being the most energy efficient. The star band settings are supplied by the Australian Greenhouse Office (AGO) and are derived from the annual total energy load, which is expressed in mega joules per metre squared per annum (MJ/M²/annum) as follows:

Table 1 Star band settings

0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
450+	<450	<360	<270	<180	<160	<140	<120	<100	<85	<70

A significant variation in annual total load could be considered as a variation that causes the star band score to alter by ±½ Star. At the time of this study, the band settings data was being reviewed by the AGO. As a result, this study will discuss the dwelling energy efficiency in terms of underlying MJ/m²/annum and not in terms of the star ratings.

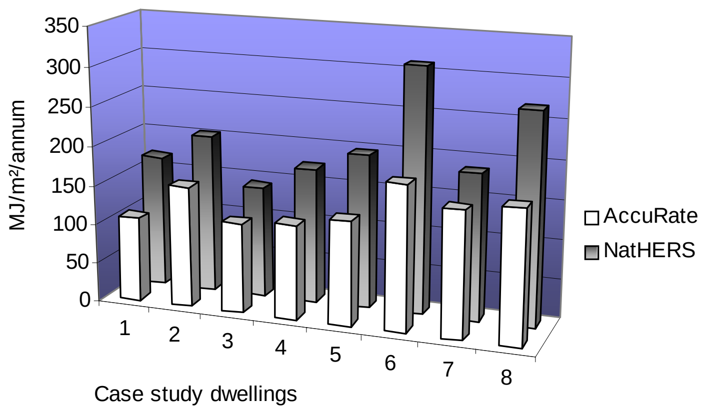
One of the drivers to improve the Nationwide House Energy Rating Scheme (NatHers) was the need to improve ventilation modelling and especially in tropical and sub-tropical climates (Commonwealth of Australia, 2004). In these climates zones, there has been concern that the current regulations, modelling and assessment tools do not address local conditions sufficiently, as evidenced by the following:

> Queensland, through intense lobbying by the Master Builders, introduced a variation to the BCA to better suit Queensland conditions relating to light weight construction and block construction *(QMBA, 2004)*

This study used AccuRate, the new thermal modelling tool developed by CSIRO. While the NatHERS ventilation model makes some provision for ventilation, it is far less detailed than AccuRate's ventilation model.

All the case study dwellings, including Research House, were modelled in AccuRate in the same climate zone to avoid variations in energy consumption due to climatic differences. Springfield, (Climate Zone 9), was selectedas a typical new subdivision. Springfield is an outer suburban Greenfield development of 2860 hectares located 23 kilometres from the Brisbane Central Business District (CBD), and expected to house some 60,000 residents by 2012. All the case study dwellings meet, or exceed, BCA 2003 DTS requirements in terms of their constructions, so the point of comparison lies between the case studies totals, as shown in Figure 12.

Figure 12 NatHERS and AccuRate - impact of improved ventilation modelling on energy efficiencies



The study found that the improved ventilation modelling resulted in a decrease of between 14 and 41 % in the annual total load between NatHERS and AccuRate. This is predominantly due to decreases in the energy used to cool the premises. As improved ventilation modelling is clearly indicated, the difference in energy efficiencies between the case study dwellings relates to the differences in the dwelling design and construction methods.

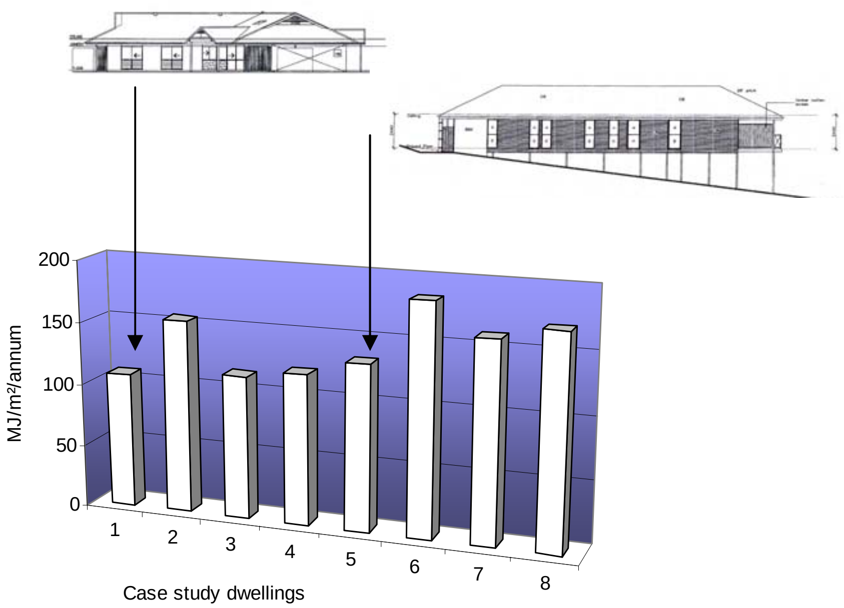
BENCHMARKING ENERGY EFFICIENCY

Early in the study that underpins this paper, industry informants noted that at present the energy efficiency requirements could be met simply through BCA deemed to satisfy (DTS) provisions. Informants also noted that there is no clear measure of how to achieve the necessary standard, or to meet increasing standards. Benchmarks are required so that industry could learn how to achieve a sustainable outcome without losing any competitive edge in the market (Mead and Wales, 2004). This is particularly important in Queensland, which has developed housing styles that differ from the more populous and cooler southern states.

Research House (case study 1, Figure 4) has set the benchmark for dwellings suited to the more traditional Greenfield 'cut and fill' slab lots and the Greensmart Home (case study 5,

Figure 8) has set the benchmark for the elevated dwellings suited to sloping sites, as shown in Figure 13. The annual loads for both these dwellings may be conservative. In case study 1, there are a number of materials and design options that could not be included in the modelling, while the final design for case study 5 included additional ventilation features that are not included in the modelling.

Figure 13 Range of energy efficiencies in new subdivisions



There is a marked variation in the range of annual total loads between the most efficient, case study 1 (107.7 MJ/M²/annum) and the least efficient, case study 6 (184.8 MJ/M²/annum) of the case study detached dwellings. While the impact of the variation is yet to be quantified in terms of star ratings, this range suggests that further design changes are required to optimise energy efficiency in new dwellings. It is timely to note that a survey of dwellings constructed in Victoria between 1990 and 1999 revealed that DTS provisions aimed at achieving a goal of 3 stars inadvertently permitted 1 star dwellings to be constructed (AGO, 1999b). Also, as the AGO notes:

> While there is overall compliance with mandatory requirements for thermal performance, it appears that the residential building industry does not always take advantage of simple or low cost design options for additional thermal efficiency (AGO, 1999b)

A number of issues arise from this snapshot of the energy efficiencies in new subdivisions:

- The results reflect the energy efficiencies of the post-BCA 2003 case study dwellings only and so do not reflect the energy consumption of the majority of the existing dwellings constructed pre-BCA 2003.
- the amount of flat land available for development in SEQ is rapidly diminishing and developers and designers are increasingly facing steep and complex sites that do not suit cut and fill techniques such as are required for slab construction
- The trend in future may be toward higher, rather than lower energy consumption.

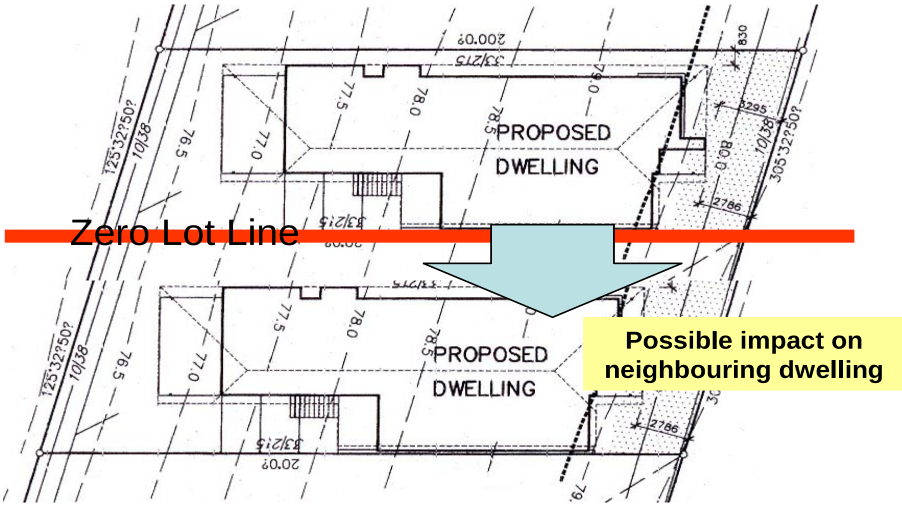
Both sub-division and dwelling designers need access to methodologies and tools to augment passive design principles and improve the thermal performance of residential dwellings as they contend with increasingly complex sites and regulations. However there is another factor that may lead to an increase in the energy required to cool residential dwellings, and that is the impact that increasing urban densities may have in reducing access to natural ventilation.

CHANGING RESIDENTIAL DEVELOPMENT PATTERNS

Australia's pattern of residential development will continue to change as suburban and urban densities increase and as the regulations governing energy efficiencies toughen. Regardless of how well designed a dwelling or subdivision may be designed, external conditions will change as the suburb matures. The most likely change is that over time, increasing suburban and urban densities (through additional structures or increasing vegetation) may shield a dwelling from access to natural ventilation. It will become increasingly important that dwelling energy efficiency be measured in terms of the dwellings context within a subdivision.

Examining one of the dwellings, case study 5, Figure 8, known to be located in close proximity to its neighbour, as shown in Figure 14, triggered an examination of the impact of increasing the external shielding for all the case study dwellings.

Figure 14 Impact of minimal boundary clearance on adjoining properties



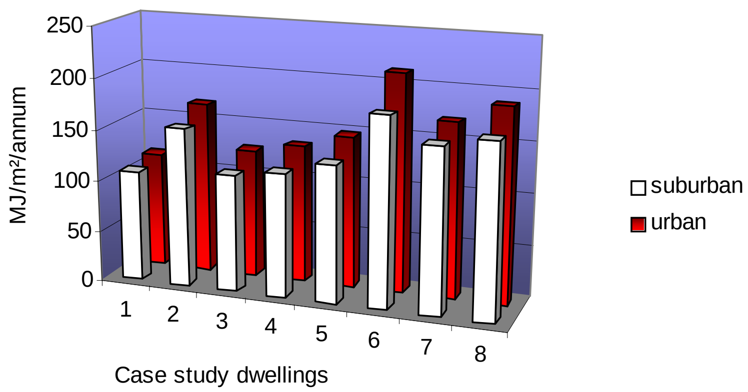
This examination was made possible because AccuRate, allows the external shielding factor to be selected from a range, which includes:

- None: no surrounding obstructions
- Light: a few surrounding obstructions (e.g. a house in the country)
- Moderate: obstructions typical of suburban housing
- Heavy: obstructions typical of inner-urban housing.

The results of the changing the external conditions by increasing the degree of external shielding, and reducing access to natural ventilation are shown in

Figure 15.

Figure 15 Impact of increased external shielding on energy efficiencies



This finding confirms and quantifies 'common knowledge' principles of orienting for ventilation. The variation in annual total loads is again important, ranging from 113.0 MJ/m²/annum (case study 1, Figure 4) to 212.9 MJ/m²/annum (case study 6, Figure 9). Because of the number of simulations involved, the worst-case combination of poor orientation and increased external shielding was not examined in detail for each of the case study dwellings. However, for case study 3 (Figure 6), which is one of the better performing dwellings, this worst-case scenario resulted in an increase in energy consumption, and a decrease in energy efficiency, of 40 MJ/m2/annum, or approximately 30 % above the optimum annual total load.

It is highly likely that in some instances a project home will be sited to suit a sub-divisional layout that is inappropriate for the dwellings design. 'Blank canvas' EER's displaying approximate star ratings throughout 360° of rotation and in a variety of urban and suburban settings, could easily be displayed on the plans as an added feature for the energy consumption conscious consumer. Importantly, if such information were readily, and reliably available throughout the design process, it would enable designers to test a range of ventilation and shading options as the design progresses, instead of forcing them to react to an inappropriate rating at the end of that process.

A number of points concerning future dwelling assessment processes arise from this discussion:

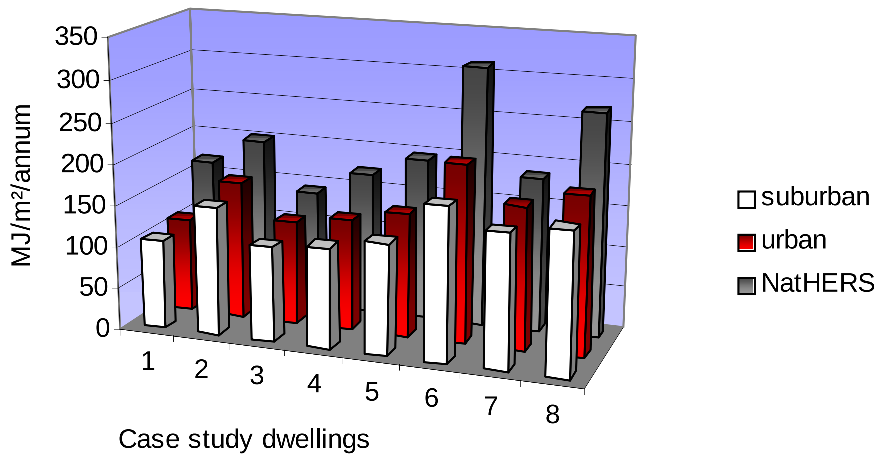
- Data on adjoining properties is rarely available at the time of rating the dwelling
- Assessors have to rely on their knowledge of the area in a paper based process
- In the absence of data on the surrounding dwellings, it would be reasonable for an assessor to assume that a suburban setting equates to a suburban selection
- Any reduction in energy loads may be sufficient to gain an additional half star if the original rating is close to one of the star band thresholds. This point is important if a dwelling is struggling to comply and as star ratings increase over time
- The shielding assumption needs to be disclosed in the ratings statement.

These are a function of the use of the programs and not of the programs' performance.

Measuring ongoing change in subdivisional residential patterns

As our suburbs change and suburban and urban densities increase, it is possible that the energy efficiency of dwellings may reduce and approach the levels indicated by the earlier NatHERS program, as shown in (Figure 16).

Figure 16 Possible impact of increasing urban densities on access to natural ventilation to cool residential dwellings



The impact of such growth and change over time has the potential to be captured through a process similar to that in use in the Australian Capital Territory (ACT), where dwelling energy efficiencies are re-assessed at point of sale.

In 1999, an AGO report into Australian Residential Building Sector Greenhouse Gas Emissions 1990-2010: noted that

> New residential dwellings account for approximately 20 % of the total housing stock. As a result some 80 % of the stock is outside the scope of this report *(AGO, 1999)*.

Also in 1999, the ACT sought to narrow this regulatory gap between existing and new stock. Since March of that year, the Energy Efficiency Ratings (Sale of Premises) Act 1997 requires the disclosure of an existing dwelling's energy rating in all sale advertisements for the premises, and provision by the vendor of an Energy Rating Report to purchasers prior to entering into a contract for sale. (ACT PLA, 2003a). According to the AGO,

> There would be some indirect market pressures if energy-efficient dwellings commanded a higher price; this is one objective of house energy rating schemes, but their influence on buyer or occupant behaviour is still unclear *(AGO, 1999)*

There is anecdotal evidence to suggest that the presence of energy efficiencies in property guides over the last few years, has heightened awareness of this issue among the owners of the 80 % of the residential market currently unaffected by increasing energy efficiency provisions. An ACT firm has been recording the price, location and energy rating of dwellings advertised for sale in the ACT over four years and has noted:

- A minor increase in value in 0 star rated dwellings, due to the impact of the aged inner-city housing stock which is valued more for the land on which it stands than for the nature of the houses themselves

- A bulge around the 2.5 star band representing the bulk of ACT housing
- A third bulge at 4 star driven by mandatory 4 star new dwellings
- A clear increase in value for 5 star rated dwellings
- A market preference for energy efficient dwellings (Energy Partners, 2003).

It would seem reasonable to assume that this trend could lead to a greater consumer awareness of energy efficiency and to increasing pressure on the accuracy of the modelling tools. Therefore, while the intent behind the ACT legislation was to extend energy efficiency provisions into the existing dwelling market, use of the latest generation of thermal tools at point of sale may also enable the ongoing assessment, examination and improvement of dwellings as suburbs and regulations continue to change.

Conclusions

This study has discussed a number of factors that need to be considered by regulators, developers, designers and industry in the journey toward creating, and maintaining energy efficient sustainable subdivisions. These include:

- The use of energy in the dwelling is the largest source of greenhouse gas emissions from Australian households
- Energy use in Queensland is quite different from the pattern for the rest of Australia
- The percentage of energy used to heat and cool dwellings is small compared to the southern states, but is set to increase air-conditioning is installed at an increasing rate
- Queensland adopted the BCA energy efficiency provisions in September 2003
- Dwelling energy efficiency is constrained by the sub-divisional layout
- The need to provide sub-divisional designers with a methodology to improve energy efficiencies
- Improved ventilation modelling in AccuRate resulted in a decrease in energy use of between 14 and 41 %
- The dwellings developed in conjunction with the Departments of Housing and Public Works have set the benchmark for slab on ground and elevated dwellings
- A snapshot of EERs in a range of dwellings that commonly occur in new subdivisions revealed a marked variation between the best (107 MJ/m^2/annum) and worst (184.8 MJ/m^2/annum) performing dwellings suggesting that further design changes are necessary to optimize energy efficiencies
- Energy efficiencies achieved by these case study dwellings do not reflect energy patterns in the 80 % of the housing stock that pre-dates the current regulations
- Increasing urban densities have the potential to restrict or block access to natural ventilation
- The need to provide designers with a tool to augment passive design principles and improve the thermal performance of residential dwellings
- ‘Blank canvas’ EER’s displaying approximate star ratings could be displayed on the plans as an added feature for the energy consumption conscious consumer
- That current regulations are likely to increase over time, leading to generations of energy efficiencies throughout the suburbs
- Point of sale assessment allows the impact of energy efficiency to extend into the existing dwelling market
- Use of the latest generation of thermal tools at point of sale may enable the ratings process to capture, examine and design for, the impact of ongoing change as suburbs and regulations change.

These are critical factors as Queensland moves to implementing a whole of government Sustainable Housing Policy and as Australia moves toward increasing energy efficiencies for new residential dwellings and toward extending energy efficiency provisions into the existing dwelling market.

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