CRC Construction Innovation
BUILDING OUR FUTURE

Sustainable Subdivisions: Energy-Efficient Design

Report to Industry

Change is occurring across Australia with new energy-efficiency regulations becoming mandatory for new residential dwellings.

The *Sustainable Subdivisions: Energy-efficient Design* Report to Industry describes the relationship between subdivisional layout and a dwelling's energy efficiency. Effective energy-efficient subdivisions will be more energy efficient than conventional developments. Energy-efficient dwellings should have lower demands on non-renewable energy sources, reduce the level of greenhouse gas emissions, and save money for owners and occupants.

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CRC AUSTRALIA

Sustainable Subdivisions:

Energy-Efficient Design

Report to Industry

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Foreword

The Cooperative Research Centre (CRC) for *Construction Innovation* is committed to leading the Australian property, design, construction and facility management industry in collaboration and innovation. We are dedicated to disseminating practical research outcomes to our industry – to improve business practice and enhance the competitiveness of our industry. Developing applied technology and management solutions, and delivering education and relevant industry information is what our CRC is all about.

Our CRC's *Sustainable Built Assets Program* identified *Sustainable Subdivisions* as one of five key thematic areas of research for 2001–2007. This publication "Sustainable Subdivisions: Energy-Efficient Design" results from of one of our leading projects led by Michael Ambrose *(CSIRO)* with a project team comprising Anne Miller *(CSIRO)*, Angelo Delsante *(CSIRO),* Michael Ball (*Queensland Department of Public Works),* Dayan Jayasekera *(Brookwater),* Peter Droege *(DEM),* John Bell *(QUT)* and Damian Dewar *(Brisbane City Council).*

We look forward to your converting the results of this CRC applied research project into tangible outcomes and working together in leading the transformation of our industry to a new era of enhanced business practices, safety and innovation within the sector.

Mr John McCarthy

Chair
CRC for *Construction Innovation*

Dr Keith Hampson

Chief Executive Officer
CRC for *Construction Innovation*

The quest for sustainability

There are many definitions of sustainability, but one of the best-known is that from the Brundtland Commission, which stated that sustainability was:

> *Meeting the needs of the present generation without compromising the ability of future generations to meet their own needs (Brundtland Commission 1987).*

Achieving this requires attention to nearly all aspects of our current way of living, especially in countries like Australia where the current ecological footprint per capita is far bigger than the world average. Consequently, dealing with sustainability is a serious undertaking, and trying to deliver sustainable living without significant change may be impossible. Nevertheless, projects such as this one, and future projects, are important steps to achieving a more sustainable future.

There are many other sustainability aspects that are directly related to developing suburbs including land degradation, human health, air pollution, water pollution and biodiversity loss. This project is but one contribution that we trust improves quality of decisions improving energy-efficiency for our community.

Endorsements for this Report to Industry

"The Sustainable Industries Division of the Environmental Protection Agency Queensland is pleased to be associated with the publication of the CRC for Construction Innovation's Report to Industry ***Sustainable Subdivisions: Energy-Efficient Design****. It focuses on energy issues pertinent to residential development in the south-east Queensland region and is a significant step in the development of a sustainable building sector and more liveable suburbs."* **Dr John Cole**, Executive Director Sustainable Industries Division, EPA

"The UDIA (Qld) supports this publication and its significant contribution towards finding cost-effective and sustainable solutions for new subdivisions throughout Queensland. The CRC for Construction Innovation's publication ***Sustainable Subdivisions: Energy-Efficient Design*** *is especially timely, given heightened community and government concern about energy efficiency, greenhouse gases and sustainable and responsible use of our land and resources."* **Mr Peter Sherrie**, President UDIA Queensland

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Sustainable Subdivisions: Energy-Efficient Design

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.

As our cities expand, developers are transforming more and more land to create future suburbs. Developers and government bodies have the opportunity to design suburbs that are not only great places to live, but are also environmentally sensitive and sustainable. Change is occurring across Australia with new energy-efficiency regulations are becoming mandatory for new residential dwellings.

This report emerging from the Cooperative Research Centre for Construction Innovation's *Sustainable Subdivisions: Energy-Efficient Design* project is the first part of a multistage sustainable subdivisions project theme and focuses on the energy performance of subdivisions. This project sought an answer to the question:

Are new subdivisions hindering the ability for new dwellings to meet new energy-efficiency requirements?

Sustainable Subdivisions: Energy-Efficient Design project

This report summarises the findings from the Sustainable Subdivisions: Energy-Efficient Design project. As new energy-efficiency regulations are developed, there will be a significant demand for information on available assessment tools for rating energy-efficient dwellings, and subdivisional issues such as orientation and solar access will become increasingly important. There will also be increased pressure for products that deliver energy efficiency, such as solar technology, glazing systems, insulation and low-energy building products and materials.

The objectives of the Sustainable Subdivisions: Energy-Efficient Design project were to:

- investigate the barriers to energy-efficient innovation, primarily caused by a disconnect between 'housing technology' and 'subdivision technology'
- assess the performance of a range of subdivisional layouts using a lot-rating tool developed by the Sustainable Development Authority (SEDA)
- assess the energy-efficiency performance of proposed dwellings using AccuRate, a new energy-rating thermal tool designed for tropical and subtropical climates
- identify benchmark dwellings that represent the issues facing developers in South-East Queensland (SEQ)
- examine a range of medium and high rise apartments ahead of new Building Code of Australian (BCA) regulations introduced in 2005
- develop criteria for possible future lot-rating methodologies to improve dwelling energy efficiencies
- recommend future research to fill gaps in existing knowledge and help develop a lot-rating methodology for SEQ.

The uniqueness of the Sustainable Subdivisions: Energy-Efficient Design project is in the linking of subdivision technology to housing technology.

What is the impact of growth on energy use?

Australia-wide, there is an increase in one- or two-person households across all age groups (Office of Urban Management 2004). This will increase demand for a diversity of housing forms to match the needs of changing household composition. At the same time Australians are living in larger houses (AGO 1999b).

Population growth

'…energy use in Queensland is quite different…'

Queensland is Australia's fastest growing state, and:

- the estimated population of the region in 2004 was 2.65 million
- this is projected to increase to 3.7 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 north from Brisbane to Noosa, south to the New South Wales border and west to Toowoomba. This region has:

- 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.

In response to a subtropical climate with warm humid summers and mild winters, SEQ has developed housing styles that differ from the more populous and cooler southern states. Mountains to the west of the region limit the amount of flat land available for residential development, forcing developers, designers and builders to adapt to an increasing number of sloping lots.

Residential energy-use growth

The use of energy (electricity and gas) is the largest source of greenhouse gas emissions from Australian households. The average household's energy use is responsible for the production of about eight tonnes of carbon dioxide (CO_2), the main greenhouse gas, per year (Reardon 2001).

Reducing energy consumption is by far the most practical and affordable way to reduce the environmental impact of residential development:

- Australia-wide, space heating and cooling, and water heating are the main energy consumers in residential dwellings (refer Figure 1)
- energy-efficient design that removes the need for heating and cooling systems, and the use of energy-efficient lighting and appliances are solutions that are available immediately and often with little, if any, cost.

Figure 1: Average energy use in Australian dwellings

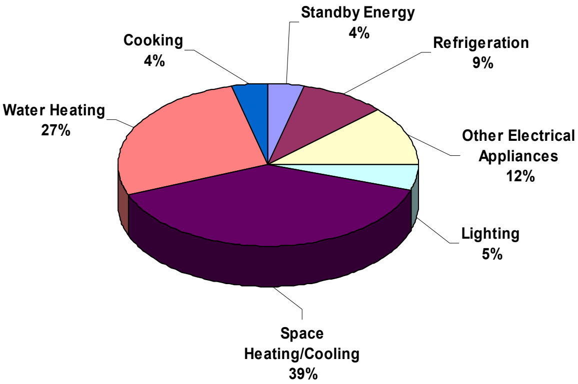
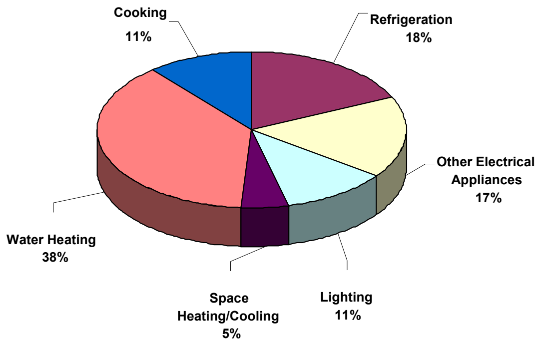


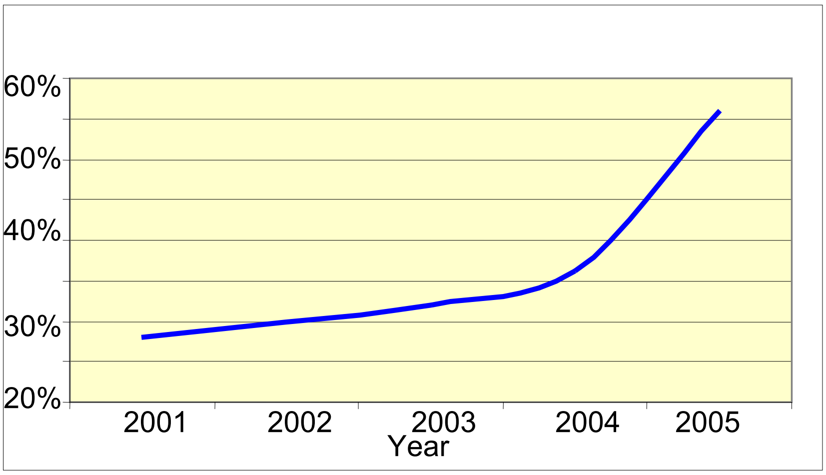
Figure 2: Queensland household energy use



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). Solar hot water systems can shift up to 90 per cent of this energy need from fossil-fuel-based sources to clean and free renewable energy sources.

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: Airconditioned households in Queensland



'…in 2001, around 28 per cent of dwellings were airconditioned, but this has increased to 36 per cent in 2004 and is expected to rise to 56 per cent by 2005…'

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).

Is climatically inappropriate design a factor behind the increase in energy use for cooling in Queensland?

Regulating energy efficiency in Australia

Energy-efficiency in buildings is increasingly being described using a ‘star rating’ system, using a 1–5 rating scale with 5 being the highest. Energy-efficiency Rating (EER) provisions for Class 1[1] dwellings were introduced in Queensland in 2003 and the required level of 3.5 stars is relatively easy to meet through Deemed to Satisfy (DTS) Provisions.

By comparison, Victoria introduced mandatory insulation requirements for Building Code of Australia (BCA) Class 1 residential buildings in 1991 (AGO 1999b). By July 2004, Victoria had moved to requiring 5-star energy ratings on all new dwellings, and introduced EER provisions for all new BCA Class 2[2] buildings.

In the Australian Capital Territory, from 1995 all new BCA Class I buildings were to achieve 4 stars through an accredited assessment process. In 1999, the ACT sought to narrow the regulatory gap between existing and new stock, and since March 1999 all houses advertised for sale must have an EER (ACT PLA 2003a). Anecdotal evidence suggests that the presence of EER in property guides over the past few years has heightened awareness among the owners of the 80 per cent of the residential market that is unaffected by increasing EER provisions in new dwellings.

Two factors emerge from this brief examination of trends in other parts of Australia:

- once energy-efficiency (EER) provisions are adopted, they tend to increase either in rigour (Victoria) or in range (ACT)
- a range of EER programs has emerged in response to the evolving regulatory framework.

EER can be expected to increase in future in Queensland, as will the range of tools and programs. To examine the correlation between lot- and dwelling-energy efficiency, this project took advantage of two such tools:

- a lot-rating methodology developed by the Sustainable Energy Development Authority (SEDA)
- a thermal simulation tool, called AccuRate, being developed by the CSIRO for the Australian Greenhouse Office (AGO) that will better handle tropical and subtropical conditions.

Barriers to energy-efficiency innovation

The Sustainable Subdivisions: Energy-Efficient Design project identified the energy-efficiency demands of dwellings from both subdivisional and individual dwelling viewpoints. As a first step, a range of key informants involved in subdivisional planning, and design and statutory compliance activities were interviewed to assess the barriers to energy-efficient design and

[1] BCA Class 1: a single dwelling that is either a detached house or one or more attached houses, each being a building separated by a fire-resistant wall.(defined in the Building Code of Australia)

[2] BCA Class 2: a building containing two or more sole-occupancy units each being a separate dwelling.

innovation. These key informants were asked to discuss market demand for sustainability practices within the subdivision and the building industry. The main issues to emerge from these discussions were that:

- the current EER standards for residential construction in Queensland can be achieved with no reliance on appropriate subdivision orientation
- other than the BCA (DTS) provisions, there is no clear measure of how to achieve the necessary standard or to meet increasing standards
- there is a need to achieve a benchmark, so that developers can achieve a sustainable outcome without losing any competitive edge in the market
- tools are required that measure energy efficiency across the whole of the industry, yet are site-specific and take into account factors such as construction materials, orientation, adjacent built forms, deciduous and evergreen vegetation, and how the home operates once occupied
- there is a need to spread sustainable energy-efficiency information among consumers, as industry will respond to consumer-driven demand
- the valuation and financial industries need to recognise sustainable practices to overcome financial barriers to using sustainable energy efficiency measures.

'…industry needs tools that measure energy efficiency, yet are site specific…'

Other key observations will be noted throughout this report.

What are solar suburbs?

Energy-efficient subdivision design is concerned with manipulating the key variables of aspect, shape and density with site or lot characteristics such as topography and slope, to achieve an optimum mix of lot sizes, appropriately oriented for solar and ventilation access. When lots are correctly aligned and proportioned, individual energy-efficient houses, with good solar access, can more readily be provided with less effort.

The Sustainable Subdivisions: Energy-Efficient Design project investigated the relationship between subdivisional layout and a dwelling's energy efficiency. Effective energy-efficient subdivisions will be more energy efficient than conventional developments. Energy-efficient dwellings should have lower demands on non-renewable energy sources, reduce the level of greenhouse gas emissions, and save money for owners and occupants.

Rating subdivision design

Just like dwellings or appliances, building lots can be rated for their energy efficiency. One such set of guidelines was developed several years ago by Sustainable Energy Authority of Victoria (SEAV), and was later modified by SEDA (SEDA 2003).

In New South Wales, SEDA requires that developers assess subdivision designs. Using the SEDA tool is simple:

- the lots are rated on their ability to accommodate a dwelling with good solar access
- like dwellings, the rating scale is 1–5 stars, with 5 being the highest
- the tool applies to separate lots between 300–1000m². For lots under 300m², access is closely integrated with building design and siting
- lots over 1000m² have a better chance of achieving good solar access

'…just like dwellings, building lots can be rated for their energy efficiency…'

- the slope of the lot will either improve or hinder solar access; however lots with a slope of over 20 per cent automatically receive a 1-star rating, regardless of slope orientation.
- the goal is to rate 5-star lots at 80 per cent of the total, with the remainder rating either 4 or 3 stars.

In the southern states of Australia, the focus is on designing to increase solar access and reduce the energy used to heat the dwelling. The aim was to test the SEDA tool for its appropriateness for SEQ, where the focus is on preventing exposure to too much sun and on capturing the prevailing breezes.

Assessing subdivision design in SEQ

In assessing a number of subdivisional layouts, the project found that, although subdivisions with larger lots (over 560m²) could achieve the SEDA guidelines, the increasingly popular, smaller lot-size subdivisions were falling well short of the mark. The following examples illustrate this outcome.

Figure 4: Subdivision 1

Figure 5: Subdivision 2

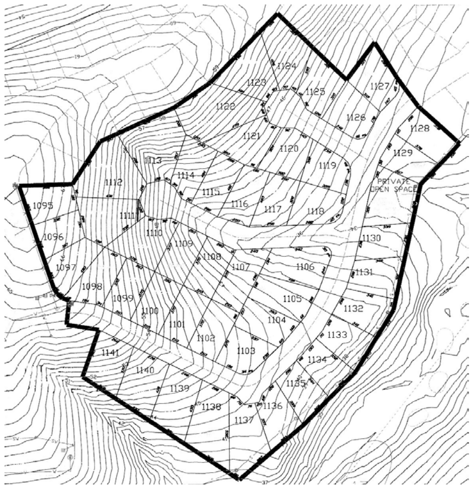


Figure 6: Subdivision 3

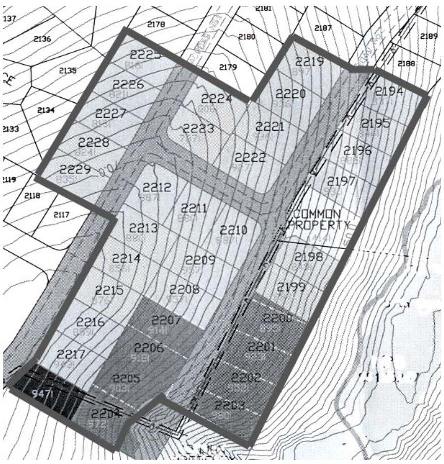
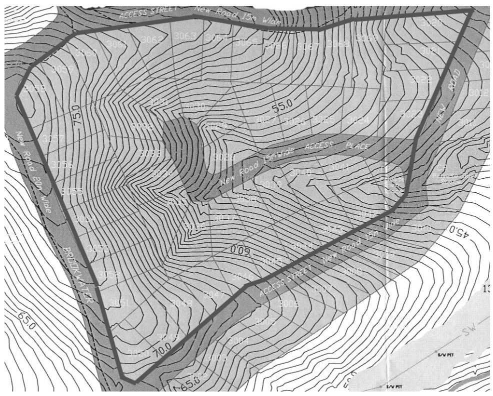


Figure 7: Subdivision 4



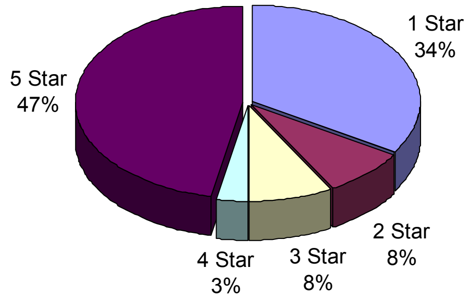
The first subdivision (Figure 4) had a high proportion (50 per cent) of small lot sizes[3], the lowest average lot size (520m²) and the lowest percentage (47 per cent) of 5-star lots (Figure 8).

In the second subdivision, the average lot size was 923m², making it easier for the lots to comply with the SEDA guidelines. Here, 91 per cent of the lots rated 5 stars.

The average size of lots in the third subdivision was 890 m² and 80 per cent of the lots rated 5 stars. Those that did not achieve this rating were steep lots (over 20%) which automatically received 1 star.

At the other end of the scale, subdivision 4 had the largest average lot size (981m²) the largest percentage of large lots[4] (30 per cent), yet had the second lowest percentage (58 per cent) of 5-star lots due in part to constraints imposed by the topography.

Figure 8: Subdivision 1 – Proportion of lot ratings

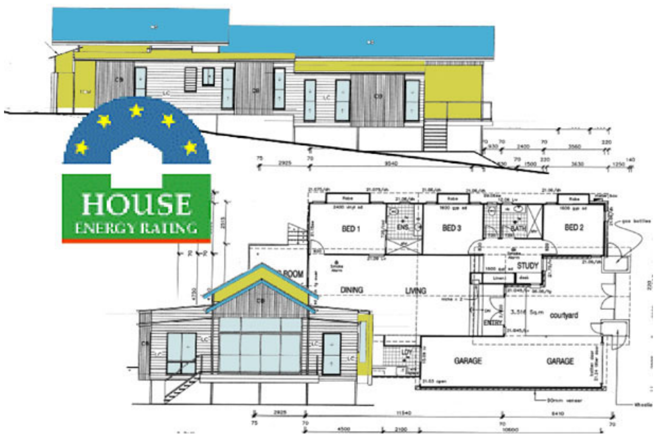


The project found that the SEDA tool is a good starting point for subdivisional design. At the very least, it quantifies the number of lots that are likely to require more intensive design solutions and alternative patterns. Using the tool could trigger a re-examination of the subdivisional layout to assess alternative layout designs.

Is there a correlation between lot rating and a dwelling's energy efficiency?

Rating dwelling energy-efficiency in South-East Queensland

Among the currently available thermal programs in Queensland, the Building Energy Rating Scheme (BERS) gives the most reliable, relevant results in tropical and subtropical climates, but BERS and, indeed, all the current thermal programs are deficient in modelling natural ventilation effectively.



One of the reasons to improve the Nationwide House Energy Rating Scheme (NatHERs) was the need to improve ventilation modelling in tropical and subtropical climates and provide designers with a tool to augment passive

[3] Based on terms used by the key informants, a 'small' lot was cited as between 400 m² and 560 m².

[4] A 'large' lot was cited as more than 560 m².

design principles and improve the thermal performance of residential dwellings (Commonwealth of Australia 2004). Another improvement will remove the ‘bias’ toward large houses (over $200m^2$) that exists in many of the current thermal programs. At present, this floor area basis of rating makes it easier for a large house to get a higher rating than it is for a small house. The program being developed to help make these improvements is called AccuRate.

A beta version of AccuRate was used to assess the energy performance of the dwellings examined for this project. Thermal programs rate dwelling energy efficiency on a scale of 1 to 5, with 5 being the highest. The star bands are determined by the Australian Greenhouse Office and are currently being reviewed. As a result, this report will discuss the dwelling ratings in terms of the underlying measure of the energy consumed in megajoules per square metre per annum (MJ/m²/annum). It should be noted that all thermal rating tools calculate the energy required to maintain the dwelling being rated within a specified comfort range using both mechanical heating and cooling systems where needed, regardless of whether they actually exist in a dwelling. Consequently, the energy consumed should not necessarily be considered the actual energy that would be consumed for a particular dwelling.

Assessing energy-efficiency of dwelling types

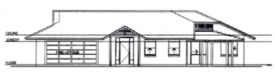
A range of dwellings types that commonly occur in new developments in SEQ were examined to provide a snapshot of energy efficiencies. The case study dwellings were modelled in locations that represent the majority of housing development in SEQ. The detached dwellings were modelled as if located in an outer suburban development and the attached dwellings were modelled as if located in an inner suburban development.

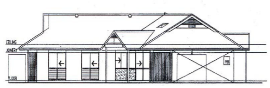
Urban sprawl means that there are increasing distances between these outer and inner developments, while the lack of coastal land available for large-scale development pushes the outer urban developments further west. As a result, there are climatic variations between the locations selected for the attached dwellings and the detached dwellings, and this variation has not been changed as the aim is to examine the comparative energy efficiency of the dwelling types where they are likely to be constructed in SEQ.

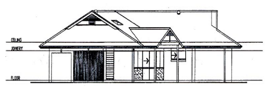
These dwelling types fall into two broad categories, detached and attached, and include:

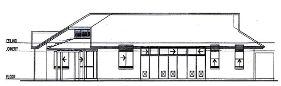
- detached — single storey — slab on ground, elevated and prefabricated
- double storey and split level
- attached — medium-density multistorey residential (2 or 3 level, walk up)
- high-density multistorey residential (over 4 storeys).

Dwelling 1









Nine detached dwellings were examined, including two research or demonstration dwellings (Dwellings 1 and 2), five project homes (Dwellings 3 to 7) and two experimental project homes (Dwellings 8 and 9).

Seven attached dwellings were examined, including four medium-density dwellings (Dwellings 10 to 13) and three high-density dwellings (Dwellings 14 to 16).

The plans do not indicate a north point as project homes are designed to be located on a range of sites with little or no alteration to the design. To aid communication, the dwellings have been colour-coded into four zones:

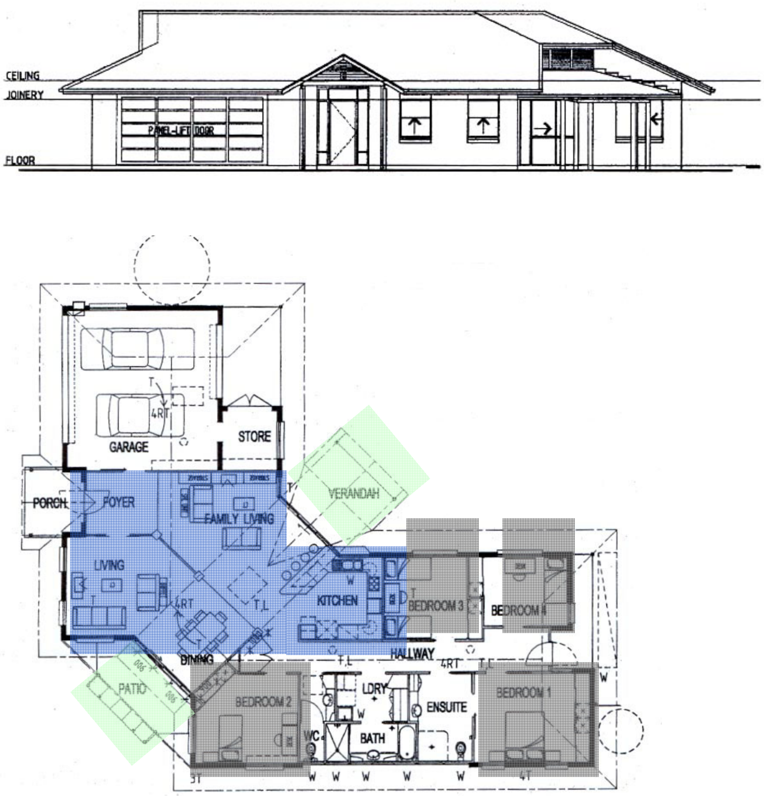
- indoor living areas, which are generally heated and cooled to maintain predetermined internal comfort temperatures in the thermal programs
- bedrooms which are generally heated or cooled at night
- utility areas (garages, bathrooms and the like) are not highlighted, as these areas are generally not airconditioned
- outdoor living areas, highlighting the importance of subtropical lifestyle considerations and shading devices in dwelling design.

The dwelling selection was restricted to plans that could be provided by project partners. The following section introduces the detached dwellings examined for this project.

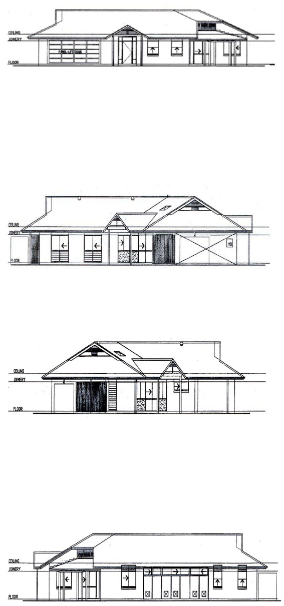
Dwelling 1

Research House, Rockhampton, was included as it was expected to set the benchmark. As the aim was to examine the type of dwelling rather than discuss specific individual dwellings, it was modelled as if located in Springfield, to create similar climatic conditions to the other detached dwellings. Springfield is a newly developed suburb 23 kilometres from Brisbane's Central Business District. The development started in 1992 and is expected to house some 60,000 residents within 20 years.

Figure 9: Dwelling 1



Dwelling 1

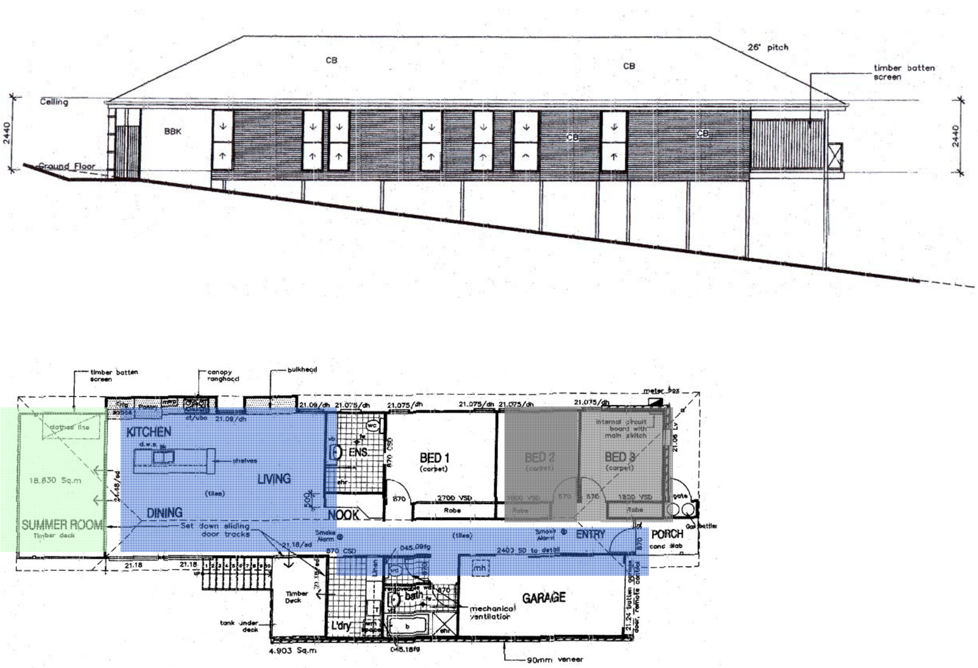


- construction is a concrete block veneer on a concrete slab, with a metal roof
- open plan layout with good cross ventilation, roof ventilation and wide eaves are incorporated into the design

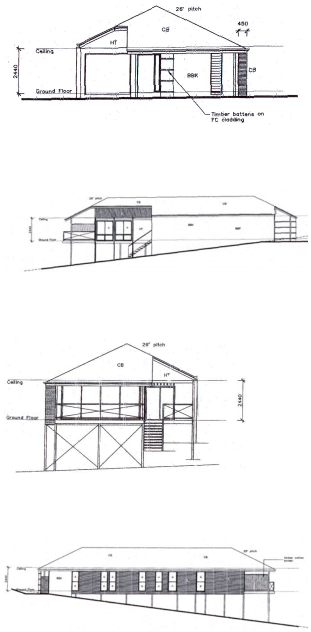
- large dwelling with 220m² internal space comprising 4 bedrooms and 2 bathrooms
- designed for traditional flat or cut-and-fill lots
- annual total load for heating and cooling is estimated to be 107.7MJ/m²/annum.

Dwelling 2
This dwelling is one of three demonstration homes at Springfield. It is located on a small lot (332 m²) with 1-star rating. Again, the aim was to examine the type of dwelling. There are some minor variations between the plans provided for this project and the actual constructed dwelling.

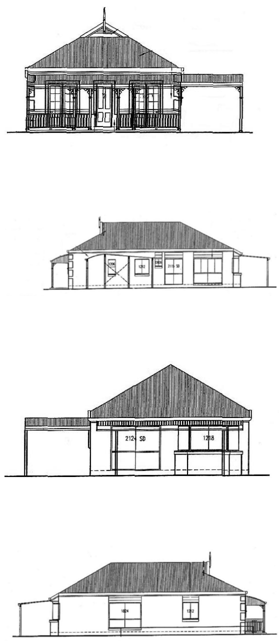
Figure 10: Dwelling 2



Dwelling 2

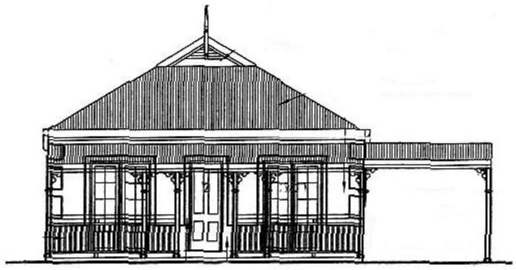


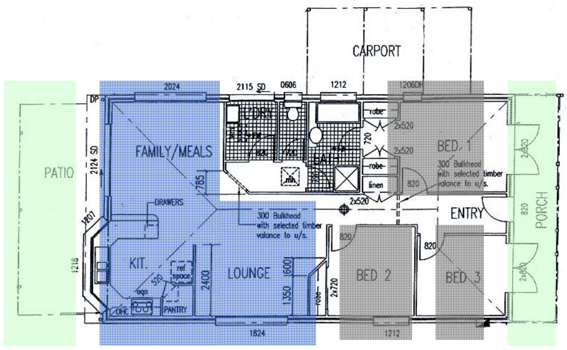
- single storey, lightweight steel clad and brick veneer on an elevated slab, with a metal roof and battened understorey (not shown above)
- small, with 150m² internal space, 3 bedrooms and 2 bathrooms
- designed for either a flat or a sloping lot
- annual total load for heating and cooling is estimated to be 133.0MJ/m²/annum.



Dwelling 3
This type of dwelling is becoming more common in new developments as lot sizes decrease in response to the ability of owners to afford them, and local authority pressures to increase densities. This dwelling was located on a small lot (300m²) with a 4-star rating.

Figure 11: Dwelling 3



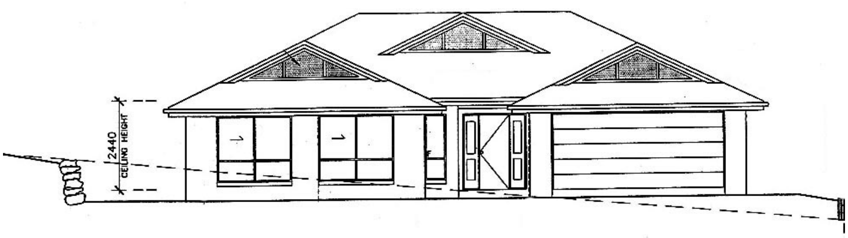


- single storey brick veneer on slab with a metal roof and no eaves on the long axis, but a covered porch on the front elevation and a covered patio on the rear elevation
- small dwelling with 104m² internal space, 3 bedrooms and 1 bathroom
- designed for a traditional flat or cut-and-fill lot
- annual total load for heating and cooling is estimated to be 114.8MJ/m²/annum.

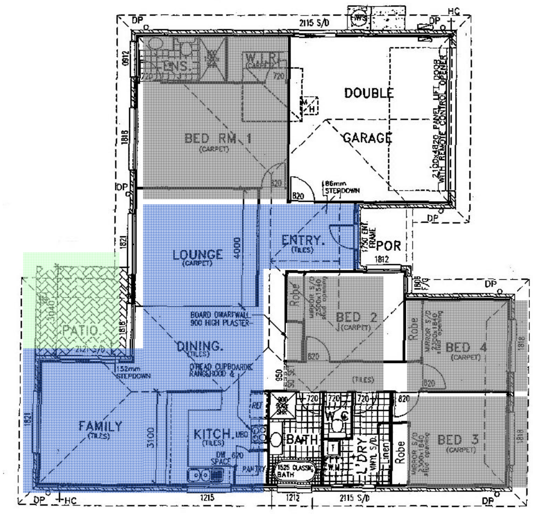
Dwelling 4

Most plans sourced for this project were variations on this theme. The dwelling was sited on a large lot (725m²), which has a 5-star rating.

Figure 12: Dwelling 4



Dwelling 4

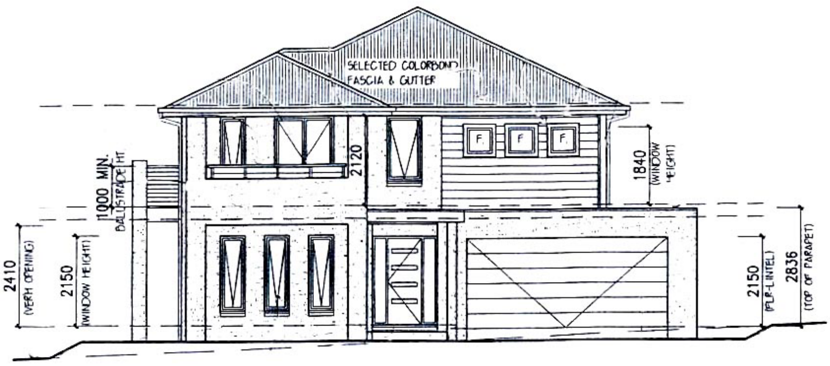


- single storey brick veneer on slab with a tiled roof, with a large internal space (nearly 200m² internal space), 4 bedrooms and 2 bathrooms
- designed for a traditional flat or cut-and-fill lot
- annual total load for heating and cooling is estimated to be 154.7MJ/m²/annum.

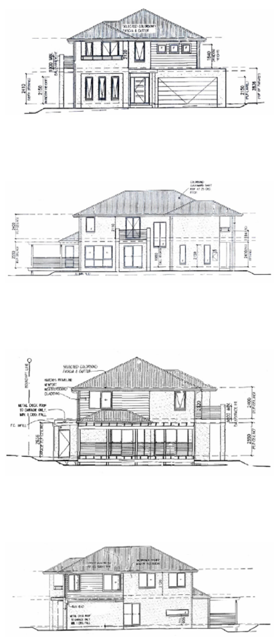
Dwelling 5

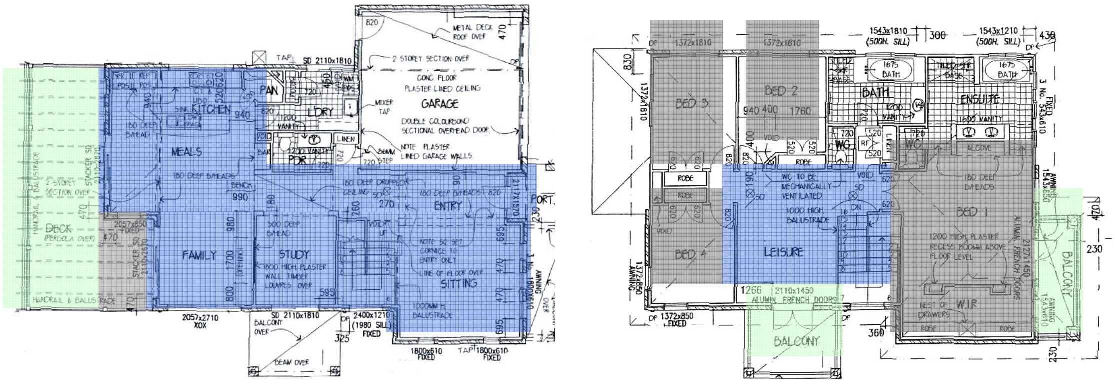
The second-most popular type among the plans sourced for this project. This dwelling was sited on a large lot (640m²), which has a 5-star rating.

Figure 13: Dwelling 5



Dwelling 5



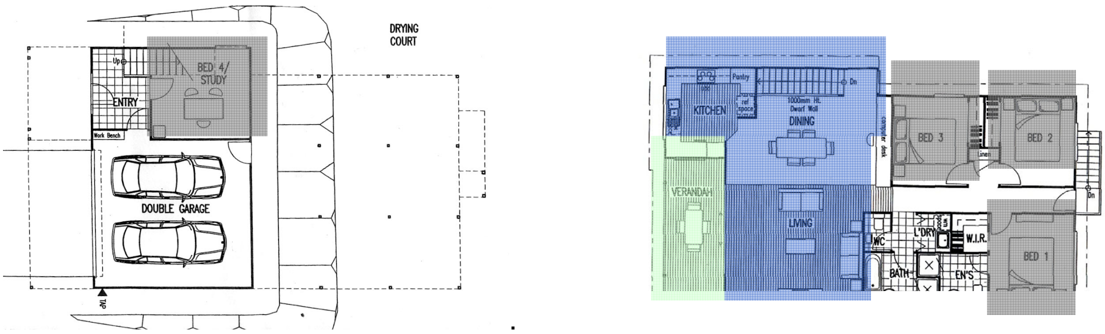


- large dwelling with 287m² internal floor space, 4 bedrooms and 3 bathrooms
- construction is two storey, brick veneer on slab with a brick veneer and lightweight clad elevated timber floor and a metal roof
- designed for a traditional flat or cut-and-fill lot
- annual total load for heating and cooling is estimated to be 120.5MJ/m²/annum.

Dwelling 6

These plans reflect a once-popular style of elevated lightweight dwelling. Dwellings like these are now more common in inner urban areas where increasing densities have created a demand for infill[5] housing. Elevations were not supplied.

Figure 14: Dwelling 6



- elevated, lightweight timber construction with garage, laundry and study at ground level and battened understorey

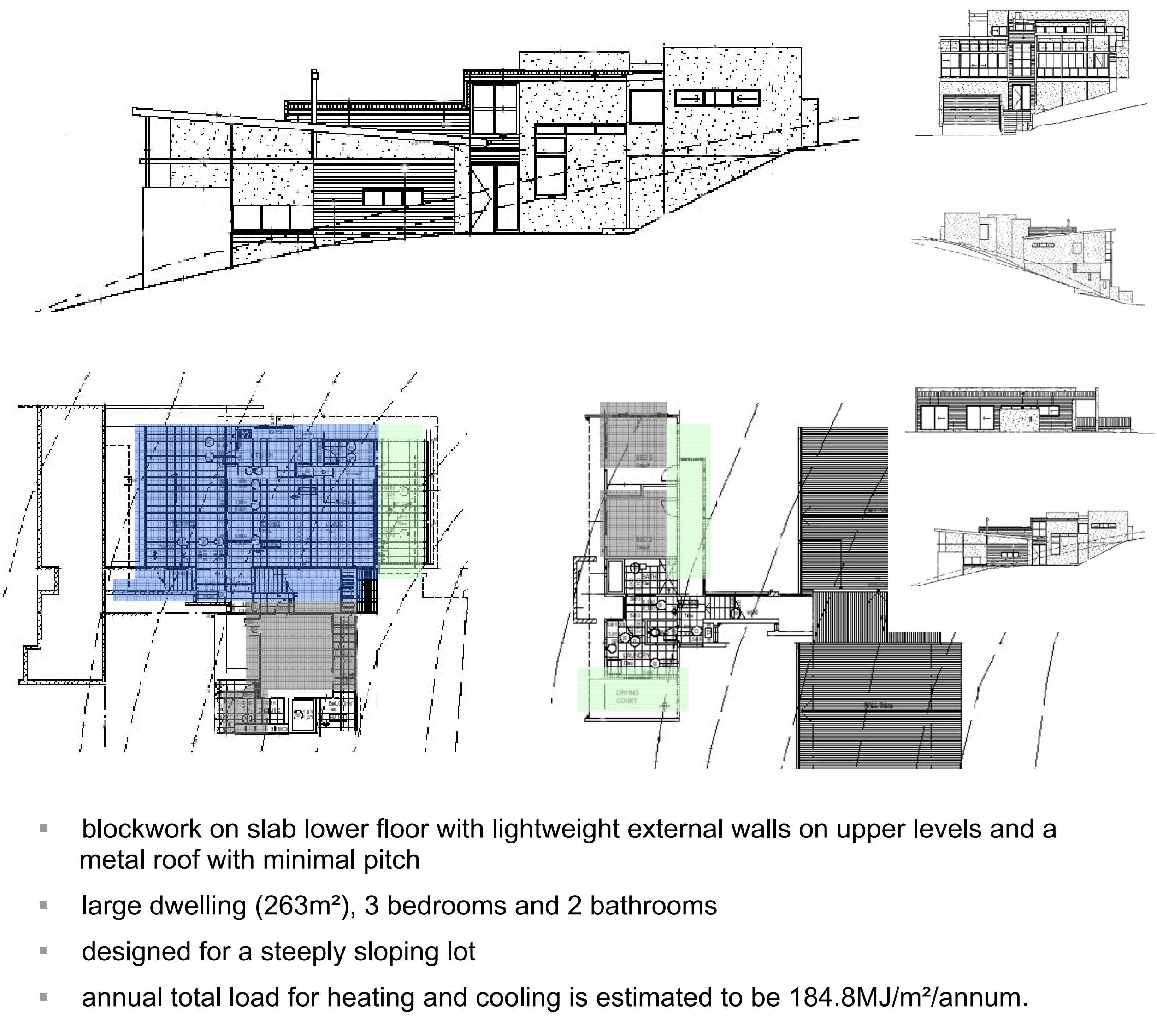
[5] This term is used to describe building a second, additional house on an existing block of land originally allotted only to the existing house, so that there are two houses on the same block.

- 189m² internal space with 3 bedrooms and 2 bathrooms
- designed for a flat or a sloping site
- annual total load for heating and cooling is estimated to be 241.1MJ/m²/annum.

Dwelling 7
This split-level dwelling with large expanses of glass to capture views and possible breezes is a type of dwelling design used where people are seeking to respond to the challenges imposed by steep slopes. This dwelling was located on a large lot (903m²) with a 5-star rating.

Dwelling 7

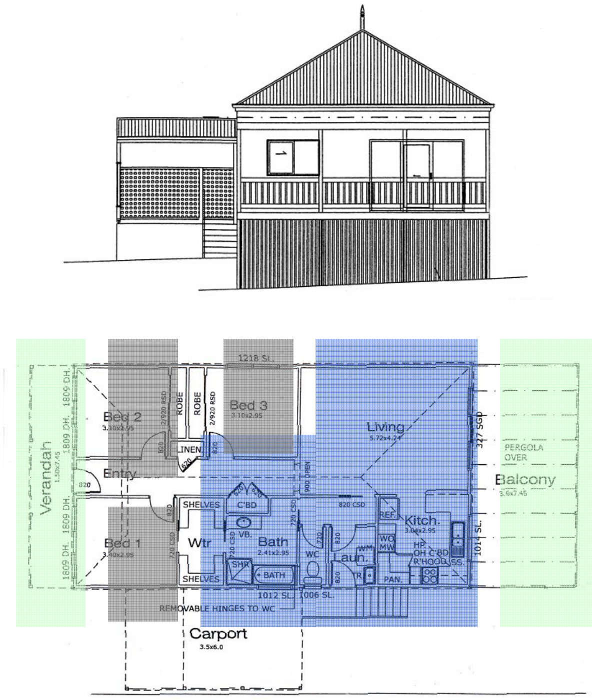
Figure 15: Dwelling 7



- blockwork on slab lower floor with lightweight external walls on upper levels and a metal roof with minimal pitch
- large dwelling (263m²), 3 bedrooms and 2 bathrooms
- designed for a steeply sloping lot
- annual total load for heating and cooling is estimated to be 184.8MJ/m²/annum.

Dwelling 8
These two experimental dwellings were developed using a prefabricated construction method. The dwellings were constructed mainly off site and then transported to site by truck. This dwelling was constructed on a small lot (261m²) with a 3-star rating.

Figure 16: Dwelling 8



Dwelling 8

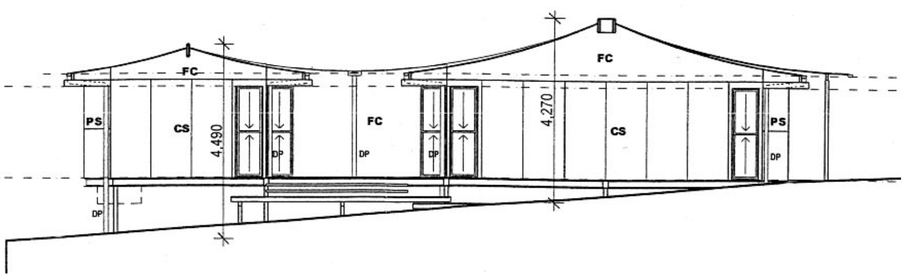
- single storey, elevated, lightweight construction, metal roof and above-standard levels of wall insulation
- small dwelling (100m²), 3 bedrooms and 1 bathroom
- designed for either a flat or a sloping lot
- annual total load for heating and cooling is estimated to be 160.3MJ/m²/annum.

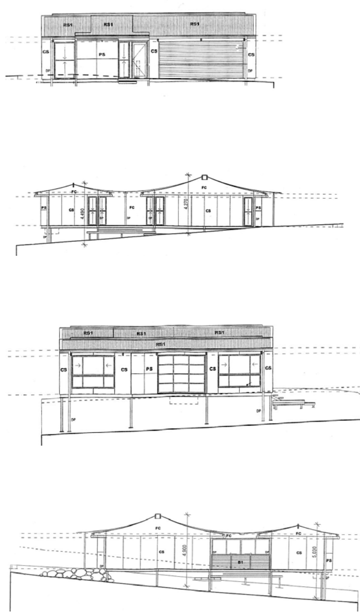
Dwelling 9

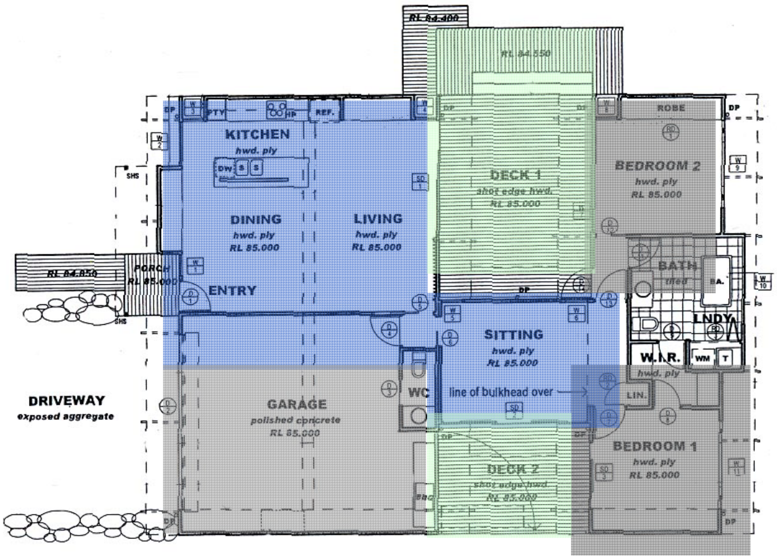
This second experimental dwelling was constructed on a small lot 402m² with a 3-star rating.

Dwelling 9

Figure 17: Dwelling 9







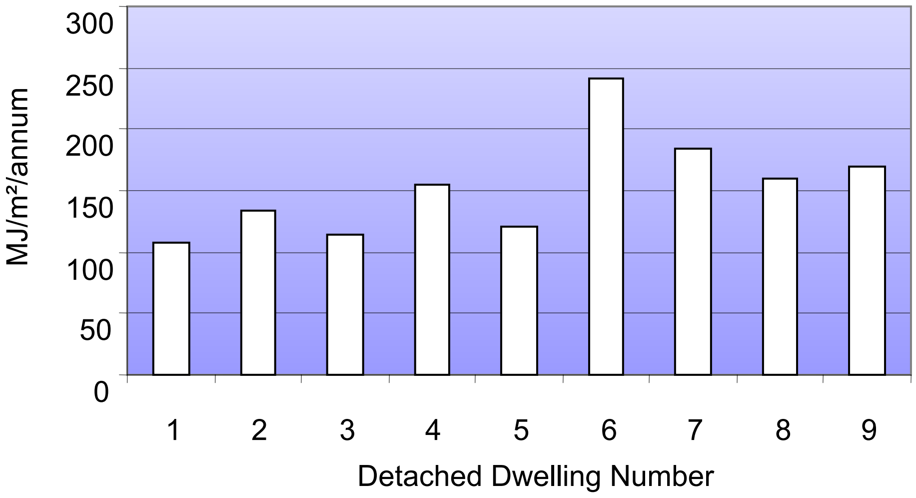
- single storey, elevated, lightweight construction, metal roof and with above-standard levels of insulation in the walls
- designed for either a flat or a sloping lot
- annual total load for heating and cooling is estimated to be 169.9MJ/m²/annum.

These dwellings represent the latest generation of demonstration, experimental and mainstream project homes and include the relatively recently introduced deemed to satisfy levels of insulation in the ceilings and external walls[6].

As shown in Figure 18, the total annual loads of energy used for heating and cooling the nine dwellings ranged from 107.7 to 241MJ/m²/annum.

[6] It should be noted that the findings discussed in this report do not reflect the energy efficiencies of most of the dwellings that exist in pre-BCA 2003 developments

Figure 18 Energy efficiencies of detached dwellings



That is to say, the least efficient dwelling was projected to consume some 220 per cent more energy than that used by the most efficient dwelling. The most energy-efficient home considered was Dwelling 1, the research and demonstration dwelling, while the least efficient was dwelling 6, the elevated lightweight dwelling which is closer to the traditional Queenslander style. This may be due in part to the way the understorey areas of these types of elevated dwellings are modelled as only rudimentary data exists for these spaces within the modelling programs.

In Queensland, elevated dwellings tend to have battened subfloor areas and there is an ongoing problem with modelling such dwellings. At present, these partially enclosed, shaded areas are considered to be subject to the same range of temperature variation as open air. Yet anecdotal evidence suggests that, for the most part, these areas are cooler than the outside air in summer. A better understanding is needed of the ventilation effects of these areas and further enhancement of thermal programs may be required to model these areas more accurately.

The range of energy efficiencies shown in Figure 18 was determined in response to specific location. However, each of these dwellings either is, or has the potential to be a project home and as such may be sited on any available lot. This report will now cover a range of lot-specific issues to integrate subdivisional design and dwelling energy efficiencies to answer the following key questions:

What is the impact of lot slope on a dwelling's energy efficiency?

What is the impact of lot orientation?

Is there a correlation between lot rating and dwelling rating?

What is the impact of lot size (subdivisional density) on a dwelling's energy efficiency?

What is the impact of increasing urban densities?

'…in Queensland, elevated dwellings tend to have battened sub-floor areas and there is an ongoing issue with modelling such dwellings…'

What is the impact of lot slope?

Yield is the most important factor when configuring lots within a development site. One of the physical elements of a site most influential on yield is the topography, which will present environmental and engineering constraints unique to each subdivision development. The amount of flat land available for development in SEQ is rapidly diminishing, and developers and designers are increasingly facing sloping and complex sites that do not suit cut-and-fill techniques with slab on ground construction. Gradual slopes are preferred to steep ones and the steeper the topography, the more constraints the site will impose on the style and form of development that can occur.

Detached dwelling types fall into two broad categories determined by the lot slope: those designed for traditional cut-and-fill lots, and those designed for sloping lots. These categories were noted in the introductory description for each dwelling.

The project found that high energy efficiency is possible and is being achieved. For example, Dwelling 1, Research House, has set the benchmark for the more traditional cut-and-fill slab dwellings for outer suburban developments. In this group, which also included Dwellings 3, 4 and 5, the least efficient was Dwelling 3, which is also the most common in new developments. There was a variation of approximately 44 per cent between the most and the least energy-efficient dwellings — a range of 107.1 to 154.1MJ/m²/annum.

Dwelling 2, has set the benchmark for dwellings designed for sloping sites. However, this dwelling has above-standard levels of insulation, and different flooring to the other dwellings. Dwellings 8 and 9 also have above-standard levels of insulation, while Dwelling 6 is a typical example of these types of dwelling. There was a variation of some 81 per cent between the most and the least energy-efficient dwellings, a range of 133.0 and 241.1MJ/m²/annum.

The main issues to arise from these variations are that:

- as regulations increase, the range of energy loads highlights the need for dwelling designers to have access to a methodology that will allow them to augment passive design principles[7] and test the energy efficiency of designs targeted for complex sites at design development
- there is a need for further research to determine the thermal performance of understorey areas.

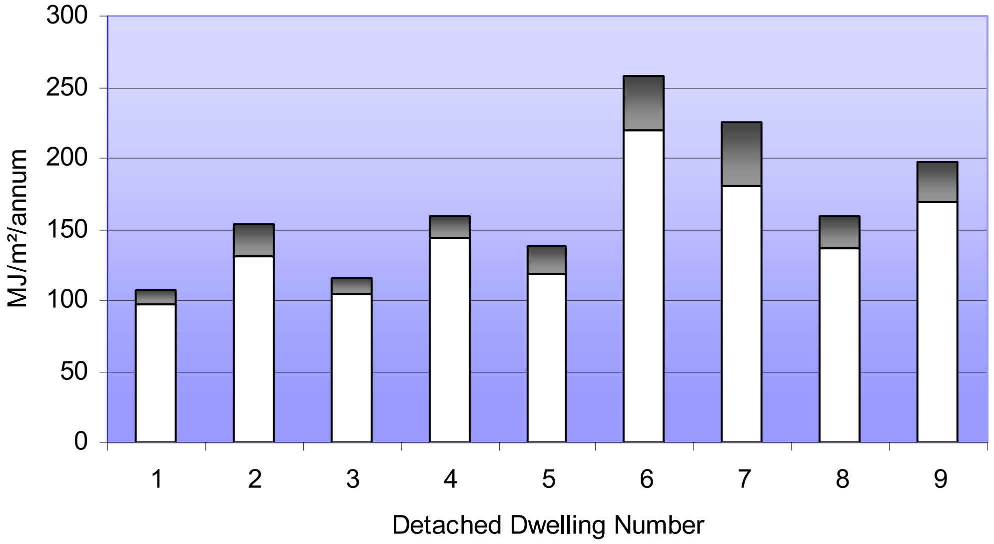
[7] Passive design is design that does not require mechanical heating or cooling. Homes that are passively designed take advantage of natural energy flows to maintain thermal comfort.

What is the impact of lot orientation?

Industry representatives consulted in this study commonly associated orientation with solar access for hot water panels or for interior heating. Disturbingly, they made little connection between orientation and access to either natural light or natural ventilation. Also of concern is that these same key informants reported that the main method of controlling indoor temperatures in project homes is by airconditioning. This disconnection between lot and dwelling technologies may be one reason for the increase in airconditioned households in Queensland referred to in Figure 3.

To assess the impact of altering the orientation on a dwelling's energy efficiency, the project homes were modelled at 45 degree increments throughout 360 degree rotation. Figure 19 shows the increase in energy between the best and worst orientations for each of the nine detached dwellings considered. The shaded area represents the variation between the best and worst energy loads for each of the dwellings.

Figure 19 Impact of lot orientation on energy efficiency — detached dwellings



Altering the orientation increased the annual total load (and decreased the energy efficiency) by between 10 and 32 per cent above the optimum levels achieved for each of the nine dwellings. Again, it is important to note the variation in annual total loads:

- at their most efficient orientation, the dwellings' total annual loads for heating and cooling ranged from 97.4 to 216.7MJ/m²/annum
- at their worst orientation, the same dwellings' loads ranged from 107.9 to 254.6MJ/m²/annum.

The variation between the best and worst energy loads for a particular dwelling was 58.4MJ/m²/annum or 32 per cent (for Dwelling 7). A common problem is that project homes are often sited on a lot that is inappropriate for the dwelling's design. 'Blank canvas' ratings displaying the total annual loads (or star ratings) throughout 360 degree rotation could be displayed on project home plans as an added feature for the energy-conscious consumer. The modelling assumptions concerning the proposed setting should also be disclosed.

This project quantifies common knowledge principles of orienting for natural ventilation and capturing breezes to cool homes without mechanical needs.

What is the impact of lot size?

Subdivision design is becoming increasingly complex. The financial viability of the development, development location, local authority requirements, consumer expectations and affordability all need to be balanced.

The residential market is also responding to changes in family structure in Australia. Smaller lots in outer suburban developments are targeted towards first-home buyers and sole-occupants. Larger lots are still expected in the outer suburbs and are often the reason why people choose to live in those locations. They are targeted towards the family market, identified by key informants as the 'second-plus'[8] or 'empty-nesters'[9] purchaser.

Regardless of family type, smaller lots are generally more acceptable in inner suburban developments, as being the trade-off for close proximity to services and facilities in the inner-city areas.

The result is a balance between small and large lots. According to the key informants, it is imperative that outer suburban developments do not appear to be 'too dense' or 'cramped'. This can happen when the developers need a higher yield to make a development pay, resulting in a higher proportion of smaller lots in traditionally large-lot outer-suburban developments.

The key informants said they received mixed messages about lot density from local authorities. Planning instruments governing development for an area often have a concept of low density, yet the regulatory bodies are increasingly insisting on higher densities. Alternatively, the local authority wants the developer to provide low-density development, but in conjunction with a high-level provision of services impossible to support with a low-density population. Complicating the issue is the developer's knowledge that prospective purchasers do not want their suburb to look overly dense, but expect infrastructure and close proximity to ongoing services. Growing population and decreasing land available for subdivision means that suburban and urban densities are set to increase.

What is the impact of increasing urban densities?

In a suburban setting, increased densities, zero lot lines , high solid fencing, close and dense foliage or high retaining walls all combine to reduce natural ventilation.

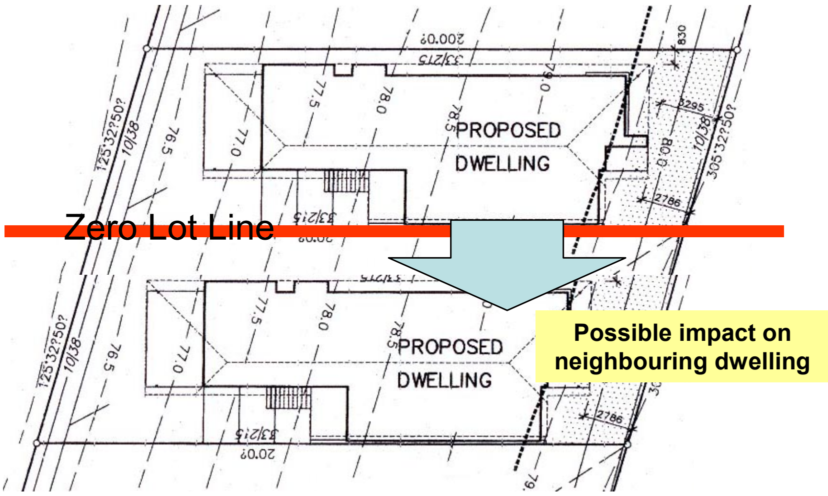
Zero lot line allotments, that is, where a dwelling wall is constructed along the boundary line, tend to be narrow, and the likelihood of a future dwelling taking advantage of being able to locate a wall along a boundary line is relatively high. The shielding effect that this has on other lots should be taken in consideration. As shown below in Figure 20, neighbouring dwellings can be close — indeed it has been observed that some dwellings are separated by

[8] 'Second-plus' purchasers have owned a home previously and this is a later or additional purchase.

[9] 'Empty nesters' are parents who have adult children no longer living with them.

less than one metre, and this close proximity greatly reduces the ability to capture breezes or sunlight for either of the dwellings along those shielded walls.

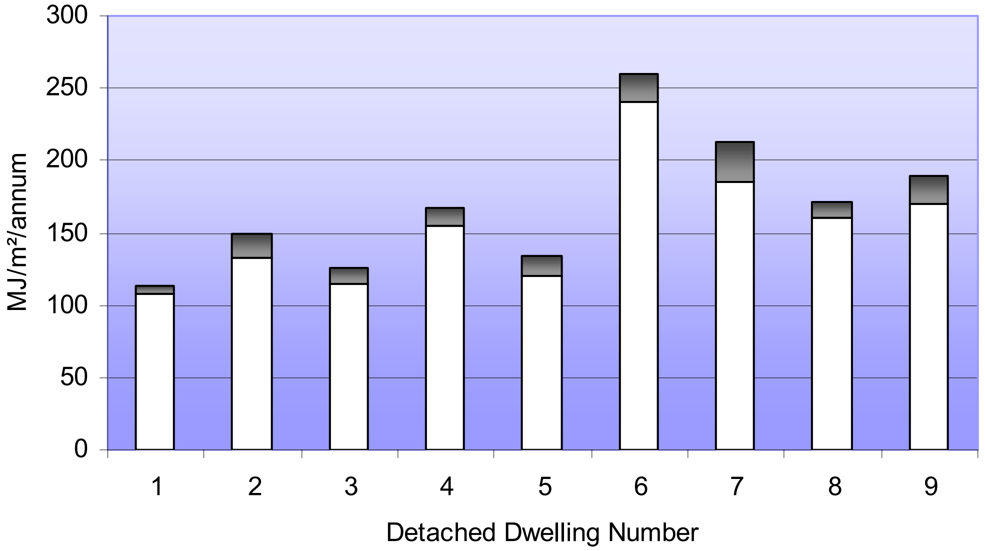
Figure 20 Impact of minimal boundary clearance on adjoining properties



To assess the impact of increasing suburban densities on a dwelling's energy efficiency, the project homes were modelled with both suburban and urban settings by increasing the degree of external 'shielding'. This change affects the wind patterns around the dwelling. This examination of the impact of increasing densities was made possible only by the AccuRate's capacity to include detailed data of adjoining structures or react to increased density settings.

Modelling the impact of increasing external shielding is the flip side of developing a more sophisticated software package that allows for increased ventilation. The results of these simulations are as shown in Figure 21:

Figure 21 Impact of increased density on energy efficiency — detached dwellings



Increasing the external shielding through, for example, an adjoining zero lot development, increased the annual total load (and a decrease in dwelling energy efficiency) by between 5 and 15 per cent above the rated levels for each dwelling. Again, it is important to note the variation in annual total loads:

- in a normal suburban setting, the dwellings ranged from 107.9 to 241.1MJ/m²/annum
- in a densely developed suburban or urban setting, the same dwellings ranged from 113.0 to 259.4MJ/m²/annum
- this range compares with that (107.9 to 254.6MJ/m²/annum) achieved by altering the orientation in a suburban setting.

The variation for the dwellings considered ranged up to 28.1MJ/m²/annum or 15 per cent for Dwelling 7.

Because of the number of simulations involved, the combined effect of poor orientation and increased urban densities was not explored in detail. In Dwelling 3, which is one of the better-performing dwellings, this worst-case combination resulted in an increase of some 40MJ/m²/annum, or 30 per cent above the optimum for that dwelling.

Increasing suburban densities may increase dwelling energy use to a similar extent as poor lot orientation.

Is there a correlation between lot and dwelling ratings?

The aim of the SEDA lot-rating methodology is to design subdivisions that increase solar access and reduce the energy used to heat the dwelling. The effects of ventilation are not considered and this is an important aspect in SEQ. In Queensland, the focus of lot orientation should be on limiting solar gain in summer and increasing access to natural ventilation. As with solar orientation, the ability of a house to capture breezes is directly linked to the orientation of the house and so orientation can be used to determine how well both these things are catered for.

The lot orientation will often dictate the orientation of a dwelling, but it is most probable that any dwelling constructed on an appropriately oriented lot will also be appropriately oriented. When the best and worst orientations were compared with those predicted by the SEDA methodology, the correlation between lot orientation and optimum energy efficiency was not as clear-cut as first thought. In six of the nine studies, the optimum orientation complied with the SEDA methodology guidelines and the same applied to the worst orientations. The problem is that in three out of the nine case studies, the SEDA methodology did not predict either the highest or lowest energy loads. As one of the aims of the project was to test the SEDA methodology for its appropriateness for SEQ, it is clear that the methodology will need to be modified for appropriate adoption in SEQ.

The SEDA methodology is a good start to assessing lot orientation — but the methodology will need to be modified for use in South-East Queensland.

Where to from here for subdivision design?

When it comes to dwelling design, it is often assumed that ventilation is the most important factor in SEQ, but solar orientation is just as important for delivering effective solar protection as it is for providing effective solar gain in the southern states. For example, poorly orientated dwellings that ignore the effects of westerly sun (which is difficult to shield from) will experience the detrimental effects in their design rating.

The case studies have also indicated that shielding is an important factor in the overall performance of a dwelling. Shielding from buildings close to a dwelling being rated has a significant effect on its ventilation capabilities. The impact of this effect is reflected in the shifts in performance that are evident in the case studies. Assessing the likelihood of shielding on a particular lot is related to the lot's width and whether the lot or any of the adjoining lots are designated as zero lot line allotments.

Weighting factors

If there is the need to assess multiple criteria (solar gain/protection, breeze access and shielding potential) the impact that each of these will have on the overall performance of a particular lot needs to be determined. Once these levels of impact have been determined, appropriate weighting factors can be assigned to each criterion and an overall rating for the lot established.

Determining the overall impact of these various factors was outside the scope of this project, but the case studies have shown that all are important in determining how well a dwelling will perform in regard to energy efficiency. Aspects such as ventilation and shielding have a much greater impact on the performance of dwellings in SEQ than they do in the southern states for which the initial lot-rating tool was developed.

Linking to other software analysis systems

One of the barriers to effectively using energy-efficiency analysis and evaluation tools for dwellings is the additional time and effort that is required to extract the data requirements and enter the information into the tools. Automatically linking such tools to other software systems already containing much of the data requirements can be a highly effective method of encouraging the use of analysis

Land subdivision is nowadays aided by the use of sophisticated tools such as Geographic Information Systems (GIS). GIS data used for land subdivision would usually contain nearly all of the information required to perform a lot rating using the methodology described above. Linking such an assessment tool to a developer's existing GIS software would enable quick and easy assessments to be made at the design stage. For dwelling designers, linking thermal programs to computer aided drafting (CAD) programs would enable quick and easy testing of a range of design options at the design development stage. Development of these links should be encourages to assist industry.

Assessing energy efficiency in attached dwellings

This section examines the performance of current design options for 'attached' dwellings in the context of an emerging energy code for medium- and high-density dwellings. The Building Code of Australia is to include energy-efficiency provisions for Class 2 dwellings from the end of 2005. Provisions already exist in Victoria.

For the purposes of this project, 'medium density' was defined as 2 or 3 level developments, while 'high density' was defined as being over 4 storeys[10].

In 1998, attached dwellings accounted for 23 per cent of the total existing housing stock in Australia and according to the Australian Greenhouse Office (AGO); this is projected to increase to 26 per cent by 2010.

Increasing populations and decreasing land supplies mean that increasing urban densities are inevitable in SEQ. Queensland's Department of Local Government and Planning (DLGP) notes that demographic changes, including an increase in single-person households, are contributing to increased demand for multi-unit dwellings (DLGP 2004).

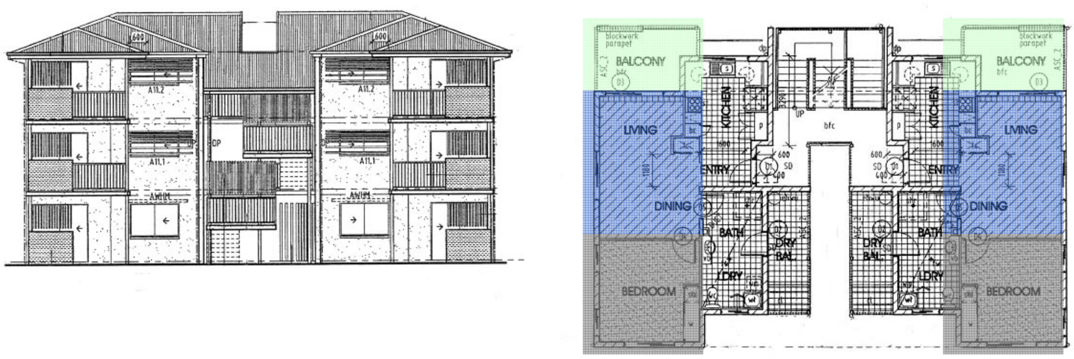
The dwelling selection made here was restricted to plans provided by the project partners. The aim was to establish the energy rating for each apartment and then examine the impact of altering the orientation. To reduce the number of variables, only mid-level apartments were examined.

The following section introduces the attached dwellings examined for this report.

Attached dwelling 10

Developments of four or six units are common in inner suburban areas in SEQ.

Figure 22 Attached dwelling 10



[10] These are common terms and may not correspond with definitions used by local authorities.

- one bedroom apartment with 57m² internal space
- mid-level apartment separated from the adjacent apartment by a covered stairwell, which acts as a breezeway.

Attached dwellings 11 - 13

Larger developments such as this are becoming more common in the inner suburbs.

Figure 23 Attached dwellings 11 - 13

- three mid-level apartments were selected from the middle floor — two outer and one inner
- 3 bedrooms, 2 bathrooms with 100–10 m² internal space
- the apartments differ in layout and footprint, and are located either above another apartment or above the garage area (these factors affect the energy efficiency).

Attached dwellings 14 - 16

High-density developments such as this are more common in inner-city areas and often located over commercial or retail outlets.

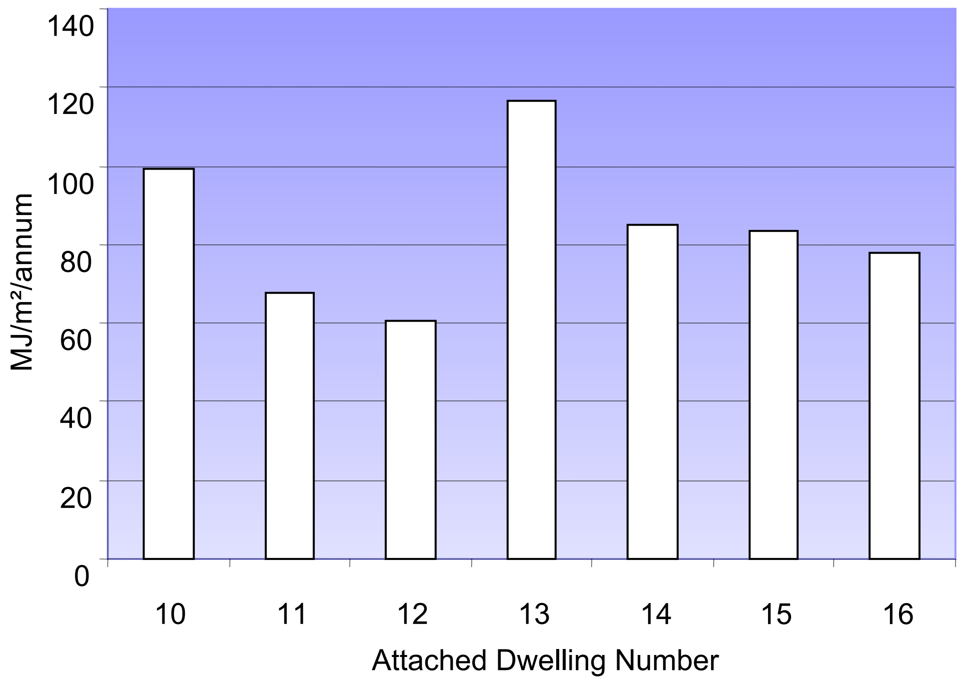
Figure 24 Attached dwellings 14 - 16

- three mid-level apartments were selected

- two, one-bedroom apartments, with 48-55m² internal space
- one, two-bedroom apartment, with 77m² internal space
- all have other apartments alongside, above and below
- all are open to an enclosed lift foyer, restricting cross flow ventilation.

The attached dwellings were modelled as if located in a densely populated inner-city area and the results are as shown in Figure 25.

Figure 25 Energy-efficiency of attached dwellings

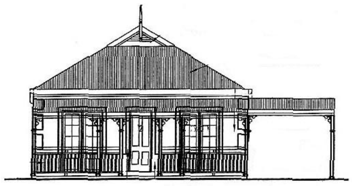


The annual total loads for the attached dwellings ranged between 60.4 and 116.4MJ/m²/annum. While these levels are low compared with the range achieved for the detached dwellings (113.0 to 259.4MJ/m²/annum), the least efficient apartment in this group still consumes some 130 per cent more energy than the most efficient apartment.

Comparative energy efficiency of attached dwellings

The AGO notes that attached dwellings are 35 per cent more efficient on a per-square-metre basis than comparable detached dwellings (AGO 1999).

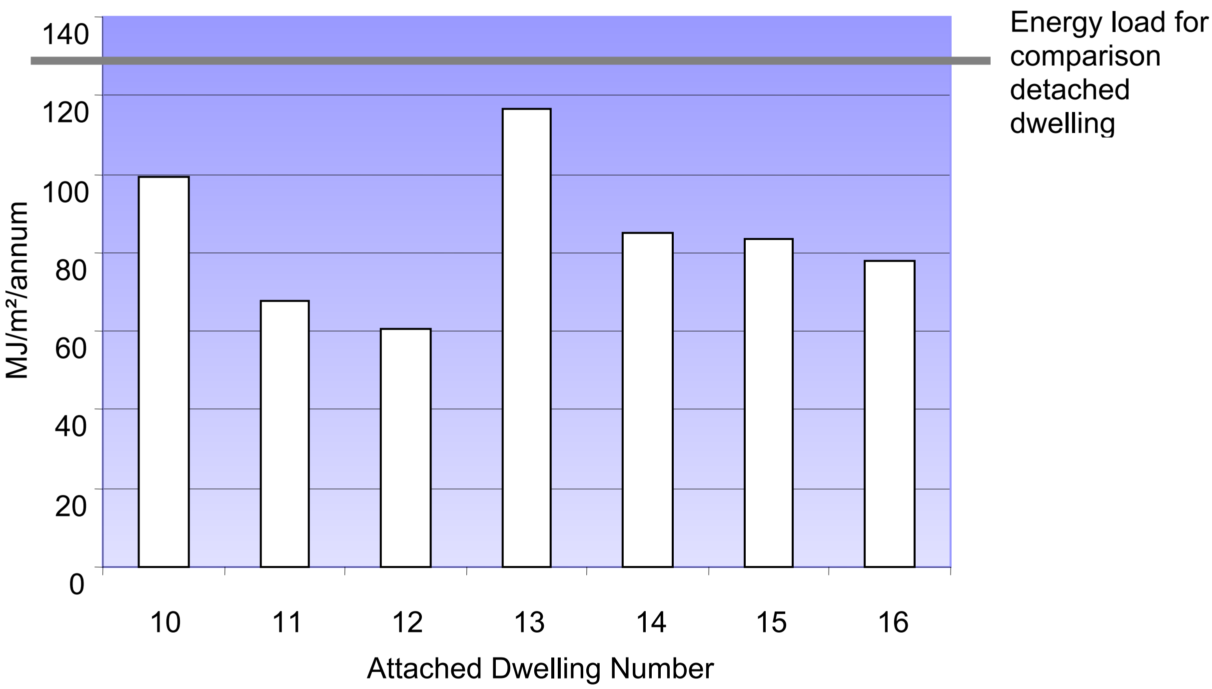
To examine the comparative energy efficiency of attached dwellings compared with detached dwellings in more detail, the case study dwellings were compared with detached Dwelling 3. This small, brick veneer on slab dwelling, was similar in size and construction to the attached dwellings.



In this instance, the detached dwelling was modelled as if located in an inner-city area adjacent to the attached dwellings (as happens in inner-city infill housing, for example).

When both the attached and detached case studies were modelled with the same degree of external shielding (heavy), the attached dwellings were significantly more efficient, with the increases in efficiencies ranging from 7 to 52 per cent — averaging 33 per cent as shown in Figure 26. This confirms the scale of AGOs finding that attached dwellings are approximately 35 per cent more efficient on a per-square-metre basis in comparison with detached dwellings.

Figure 26 Comparative energy efficiencies of attached dwellings vs detached dwellings



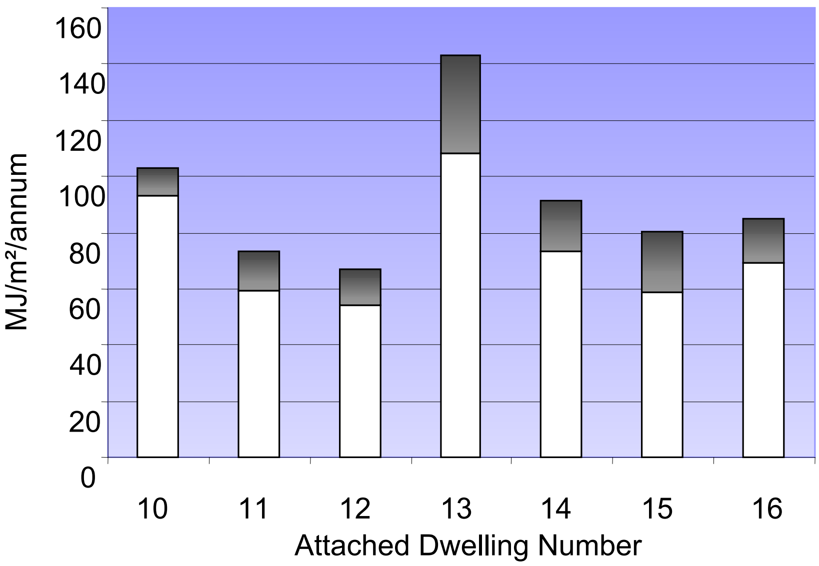
As shown in Figure 26, the most efficient dwelling was Dwelling 12, which had dwellings on either side as well as above and below. By comparison, the least efficient attached dwelling was attached Dwelling 13, which had the least area of wall, floor and ceiling spaces shared with adjacent dwellings. This would suggest that as more surface areas are exposed to the external environment, the higher the annual energy total loads.

Impact of orientation

To assess the impact of orientation on energy efficiency, the apartments were modelled throughout 360 degrees of rotation at 45 degree increments with the results shown in Figure 27.

'…designers need to note the range of energy loads within a development as new legislation is likely to demand a high standard for *all* apartments in a development …'

Figure 27 Impact of orientation on energy-efficiency — attached dwelling



Orientation plays a significant role in the energy efficiency of attached apartments, with the annual total loads varying by between 11 and 32 per cent. In general, these variations were recorded against performance totals that were low (54.0 to 108.3MJ/m²/annum) when compared to the detached dwellings (97.4 to 216.7MJ/m²/annum). Designers need to note the range of energy loads within a development as new legislation is likely to demand a high standard for *all* apartments in a development.

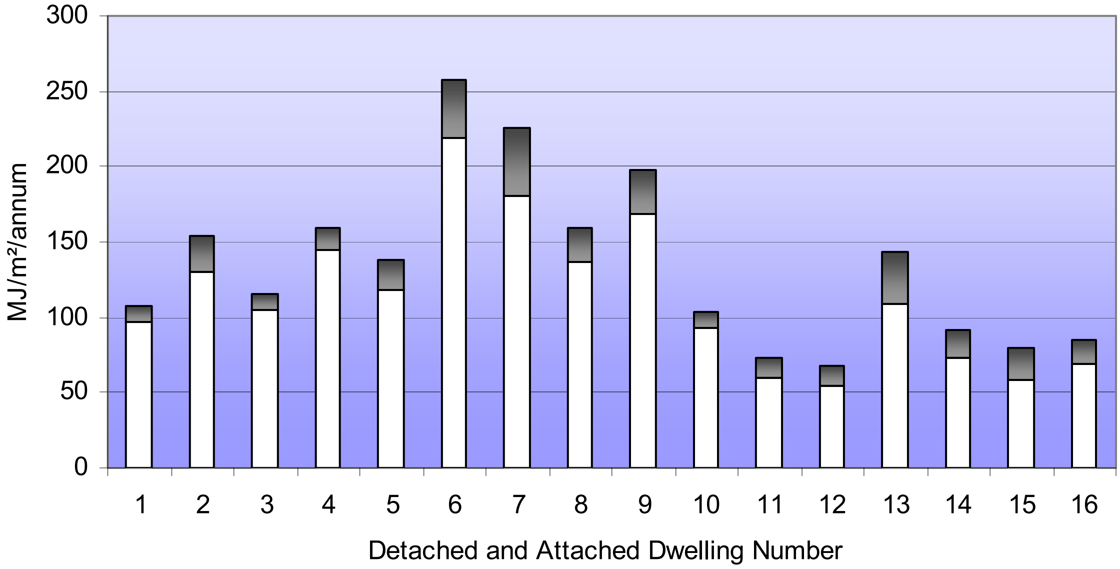
Summary

This project has examined the performance of 16 contemporary dwellings including:

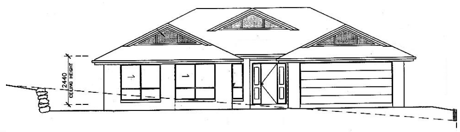
- detached — single storey — slab on ground, elevated and prefabricated
- double storey and split level
- attached — medium-density multistorey residential (2 or 3 level, walk up)
- high-density multistorey residential (over 4 storeys).

When the orientation data for the detached and attached dwellings examined for this project are combined, the range of annual total loads achieved (Figure 28) is of concern as energy-efficiency regulations increase.

Figure 28 Comparative energy efficiencies of detached and attached dwellings



The project has found that, at present, both high-set and slab dwellings can be constructed to high standards in Queensland. While there are a number of benchmark dwellings, at the subdivisional level very few dwellings would be expected to exceed current standards.



Medium- and high-density multistorey apartments also perform well and can be up to 50 per cent more efficient than the equivalent-sized detached dwelling. On average, attached dwellings are 35 per cent more energy efficient than detached dwellings.

The effect of external barriers, shielding and ventilation, play an important part in the overall comfort levels that each dwelling can offer.

Next steps

The importance of sustainability is slowly gaining recognition within all industries and the land development and building industry is no exception. Presently, although tools and methodologies exist for assessing buildings, there are no such tools or well-established methodologies for land development. This project has found that there is a correlation between the energy-efficiency of a dwelling and the land it is built on, and that lot-related issues play an important part in the overall efficiency that a dwelling is able to achieve. The challenge for subdivisional land developers is to assess the likely impact that their design will have on these future dwellings. Policy analysts also need to be aware of the potential improvements in energy-efficiency through better matching housing and subdivisional layout and local influences such as shielding.

Assessment of the existing lot-rating methodology has found that it goes only part way in assessing housing development in SEQ. The current SEDA-based methodology only assesses the impact of solar gain/protection. For SEQ, the importance of ventilation, shielding and zero lot lines needs to be incorporated into any future methodology. It is important that such methodologies, or tools, are easy and quick to use, allowing users to quickly assess the impact of certain lot-design options. Integrating methodologies or tools to existing software is considered one of the best methods for achieving this.

The drive for developing sustainable subdivisions is gaining momentum as developers, builders and government realise the important benefits that such subdivisions can bring to their residents. Subdivisions that are designed to encourage sustainable dwellings will provide residents with a home that is more comfortable to live in, has lower running costs and has less impact on the environment. These new sustainable subdivisions will become our suburbs of the future and will help in delivering the overall aim of sustainability which is meeting the needs of the present generation without compromising the ability of future generations to meet their own needs.

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Sustainable Subdivisions: Energy-Efficient Design

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*"The Sustainable Industries Division of the Environmental Protection Agency Queensland is pleased to be associated with the publication of the CRC for Construction Innovation's Report to Industry **Sustainable Subdivisions: Energy-Efficient Design**. It focuses on energy issues pertinent to residential development in the south-east Queensland region and is a significant step in the development of a sustainable building sector and more liveable suburbs."*

Dr John Cole, Executive Director Sustainable Industries Division, EPA

UDIA Urban Development Institute of Australia QUEENSLAND

*"The UDIA (Qld) supports this publication and its significant contribution towards finding cost-effective and sustainable solutions for new subdivisions throughout Queensland. The CRC for Construction Innovation's publication **Sustainable Subdivisions: Energy-Efficient Design** is especially timely, given heightened community and government concern about energy efficiency, greenhouse gases and sustainable and responsible use of our land and resources."*

Mr Peter Sherrie, President UDIA Queensland

CRC Construction Innovation
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Copies of this Report to Industry will be available from:

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