Sustainable Sub-divisions Energy Efficient Design

Report 2002-063-B-02

Anne Miller and Michael Ambrose

The research described in this report was carried out by

Project Leader	Michael Ambrose
Team Members	Michael Ambrose, Anne Miller, Angelo Delsante,
	Michael Ball, Dayan Jayasekera,
	Peter Droege, John Bell, Helen Caswell

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Authors

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Please direct all enquiries to:

Chief Executive Officer

Cooperative Research Centre for Construction Innovation

9th Floor, L Block, QUT, 2 George St

Brisbane Qld 4000

AUSTRALIA

T: 61 7 3864 1393

F: 61 7 3864 9151

E: enquiries@construction-innovation.info

W: www.construction-innovation.info

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ABBREVIATIONS

ABCB	Australian Building Code Board
ABEC	Australian Building Energy Council
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
ACTHERS	ACT House Energy Rating Scheme
AGO	Australian Greenhouse Office
BCA	Building Code of Australia
BECA	Building Energy Code of Australia
BERS	Building Energy Rating System
BiPV	Building Integrated Photovoltaic
CBD	Central Business District
CO_2	Carbon Dioxide
CRC-CI	Cooperative Research Centre for Construction Innovation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DoH	Department of Housing
DTS	Deemed to Satisfy
EER	Energy Efficiency Rating
EVA	Ethylene Vinyl Acetate
GHG	Greenhouse Gas
GIS	Geographic Information Systems
HAWT	Horizontal Axis Wind Turbine
HER	House Energy Rating
KGUV	Kelvin Grove Urban Village
kW	Kilowatt
kWh	Kilowatt Hour
kWp	Killotwatt Peak
LED	Light Emitting Diodes
MJ	Megajoules
mW	Mega watts
mWe	Mega watt equivalents
NatHERS	Nationwide House Energy Rating Scheme
PV	Photovoltaic
QDPW	Queensland Department of Public Works
QUT	Queensland University of Technology
SEAV	Sustainable Energy Authority Victoria
SEDA	Sustainable Energy Development Authority

SEQ	South East Queensland
SHW	Solar Hot Water
SOHO	Small Office, Home Office
VAWT	Vertical Axis Wind Turbine
VicHERS	Victorian House Energy Rating Scheme

PREFACE

The major project in the Sustainable Built Assets core area is the Sustainable Sub-divisions – Energy Efficient Design Project that is the first stage of a planned series of research projects focusing on sustainable subdivisions. The initial project focus is on energy efficiency and looks at the link between dwelling energy efficiency and sub-divisional layout. In addition, the potential for on site electricity generation, especially in medium and high-density developments, is also examined. Future projects are planned to investigate water conservation and waste minimization.

The first report (Report 2002-063-B-01) summarised the results from a series of industry interviews that were conducted to ascertain the drivers and barriers to energy efficient sub-division design.

This report (Report 2002-063-B-02) summarises the results from a series of cases studies that examined the link between sub-divisional layout and dwelling energy efficiency. It also investigates the potential for on site electricity generation.

EXECUTIVE SUMMARY

Australia's current pattern of residential development is resulting in urban sprawl and highlights the necessity for development to be more sustainable to avoid unnecessary demand on natural resources and to prevent environmental degradation and to safeguard the environment for future generations. This report summarises the results from a series of cases studies that examined the link between sub-divisional layout and dwelling energy efficiency, the possibility for a lot-rating tool and the potential for on site electricity generation.

Objective

The objectives of the study were to:

- Assess and benchmark the energy efficiency performance of proposed dwellings against national energy standards using a new energy-rating tool. The performance of this new rating tool will be compared against the current rating tool that is used in South East Queensland (SEQ);
- Highlight challenges for the national housing industry with the release of new energy efficiency codes;
- Explore the technologies available to housing and sub-divisions for on-site electricity generation as a basis for the development of solar suburbs, including receptivity by electricity supply companies;
- Develop a set of criteria for possible future tools to prioritise options for improving dwelling designs to bring their energy efficiency up to the desired standard;
- Investigate barriers to energy efficient innovation, primarily because of disconnection between 'housing technology' and 'sub-division technology'.

Assessing and benchmarking energy efficiency

The study examined the energy efficiency of a range of contemporary dwelling types, such as: detached single storey – slab on ground, elevated and pre-fabricated; detached double storey and split level; attached medium density multi-storey residential (2 or 3 level, walk up); and attached high density multi-storey residential (over 4 storeys).

The study found that orientation plays a significant role in energy efficiency. Using the newer thermal program, the case study dwellings were oriented throughout 360° and the annual total energy loads varied increased above the optimum by between 4 and 32 %. The dwelling that was impacted upon least by altering the orientation was Research dwelling, which recorded only a 4 % alteration in the annual total load. The dwelling that was impacted on most significantly was the type of spilt level lightweight elevated design that is seeking to respond to the challenges imposed by increasingly steep slopes and restrictions on cut and fill techniques that have dominated new sub-divisions until recent times.

The main finding from this study is the impact on energy loads that result from increased suburban and urban densities. This study was triggered from within the project by the high percentage of small lots, coupled with key informants identifying increasing densities in Greenfield developments as an issue. Using the newer thermal program, the case study dwellings were modelled at the presented orientations using two levels of external shielding and the annual total energy loads increased by between 5 and 15 %. This impact either exceeded, or was similar in range and total to the impact of altering the orientation alone. Examining the combined impact of poor orientation and increased external shielding had to be restricted because of the number of simulations involved. However, in the case study examined, this combined impact created an increase of 30 % in the annual total load.

Both the detached and attached dwellings recorded similar variations in total annual energy load in relation to altering the orientation and to increasing the shielding. However, the attached dwellings were between 7 to 50 % more efficient than similar sized attached dwellings. The level of comparative efficiency reduced as the number of conditioned spaces adjoining each apartment (alongside, above or below) lessened and the apartment came to function more as a separate dwelling.

Lot rating tool

The study found that a methodology for rating sustainability within subdivisions is required. The study utilised a rating methodology that was developed several years ago by Sustainable Energy Authority of Victoria and was later modified by Sustainable Energy Development Authority (SEDA) (SEDA, 2003) and evaluated its appropriateness for SEQ.

The SEDA methodology is a simple three-step process;

- Determine the orientation of an allotment (lot) along its long boundary with the long boundary being within 30^{o} east and 20^{o} west of true solar north. Lots outside these orientations receive a 1 Star rating;
- Determine the width of the block;
- Determine the star rating by finding which width band a lot falls into with corrections allowing for slope.

An initial trial of this methodology was undertaken on several new subdivisions in SEQ to see if the SEDA design guidelines of at least 80 % of lots rating 5 stars with the remainder rating either 4 or 3 stars were being achieved. The findings found that although subdivisions with large lot sizes (>560m²) were able to achieve the guidelines, more typical smaller lot size subdivisions were falling well short of the mark. However, results from the dwelling case studies revealed that ventilation and shielding play an important part in the overall energy efficiency of dwellings in SEQ, a factor the SEDA tool does not consider. Therefore, it has been suggested that although the SEDA tool provides a good start, ventilation and shielding considerations would need to be included in the tool.

On site energy generation

Reducing energy consumption is by far the most practical and affordable way to reduce the environmental impact of residential development. 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 implication. For Queensland, the single biggest consumer of energy in the dwelling is for hot water heating. The use of solar hot water systems can shift up to 90 % of this energy need from fossil fuel based sources to clean and free renewable energy sources. Although solar hot water systems do not actually produce electricity, the savings they make by shifting the energy need away from electricity are so significant that if all homes in Queensland were to adopt solar hot water heating the electricity savings would remove the need for additional power stations for many years.

Although energy efficiency and solar hot water systems can deliver enormous savings, the need for electricity is still growing and alternative decentralised sources are a real option. Photovoltaic cells, wind generators and co generation plants are all now viable options within community developments, although pay back periods can still be many years. Nevertheless, as the technology advances and uptake increases these payback periods can be expected to reduce making such schemes much more attractive to developers of new communities.

Next steps

This project was the first part in what is planned to be a series of scoping studies exploring a broad range of sustainability issues that are facing new subdivisions. The focus for this project was on energy efficiency and its link between dwelling energy efficiency and sub-divisional layout. Future projects are planned to investigate water sustainability and waste minimization.

1. INTRODUCTION

This report is a component of the Cooperative Research Centre for Construction Innovation project 2002-063-B Sustainable Sub-divisions:1 Energy Efficient Design. The Project Brief is at Appendix A. This project is the first of a multi-stage sustainable sub-divisions project theme and focuses on the energy performance of sub-divisions. It is anticipated that future projects will complement this one, and concentrate on associate issues such as water and waste reduction.

This project consists of two discrete phases.

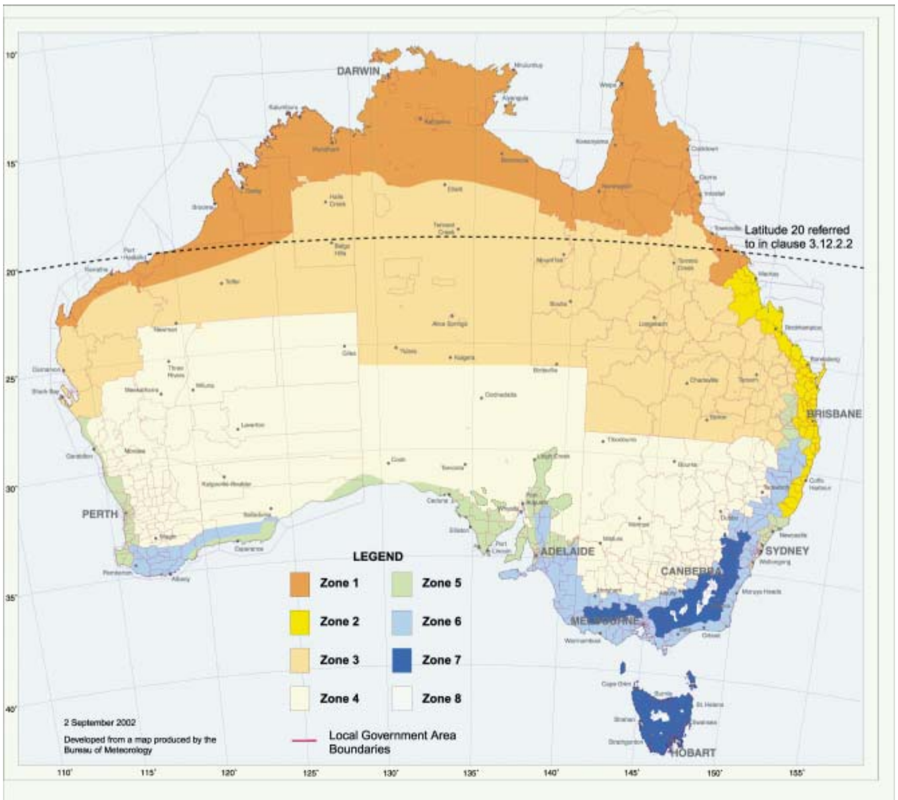
- Phase One involved a series of interviews with industry stakeholders, carried out to determine the 'current state of play' in sub-division practices. Responses from interviews with industry representatives have complemented workshops that focus on energy-efficiency and sustainability of residential sub-division practices. This has been an essential part of the research, invaluable to understanding the current knowledge base and practices involved when designing sub-divisions. An interim report on Phase One was submitted in May 2004 and the final report submitted in October 2004.
- Phase Two involved the analysis of a range of various dwelling types constructed on different size lots. Each analysis consisted of a comparison and assessment of the current energy efficiency standards using the current rating tools, NatHERS (Nationwide Housing Energy Rating Scheme) and BERS (Building Energy Rating System). The study also used a new thermal energy assessment tool, AccuRate, which has been developed to determine the energy performance of dwellings, particularly in the sub-tropical climates. AccuRate is a significantly enhanced version of NatHERS. It takes into account not only the physical built form, but specific site elements, such as orientation and access to natural breezes. Implicit in an examination of ventilation is an examination of the impact on energy efficiencies when external barriers block natural ventilation. Phase Two also examined a lot rating tool to develop criteria for a similar tool for SEQ. Finally, Phase Two undertook an exploration of the technologies available to housing and sub-divisions for on-site energy generation. This is the final report for Phase Two.

1.1 Objectives

The objectives of the study were to:

- Assess and benchmark the energy efficiency performance of proposed dwellings (including non-standard detached housing, project homes, medium density housing and high rise) against national energy standards, as contained in the Building Code of Australia (BCA), at a number of sub-division sites using a new energy assessment and rating tool which better takes into account ventilation, particularly in sub-tropical areas as indicated by Zone 2 in Figure 1 below which shows the climate zones of Australia as defined by the current Building Code of Australia, Volume 2 (Amendment 12). The performance of this new rating tool will be compared against the current rating tool that is used in SEQ, which is called BERS (Building Energy Rating System).

Figure 1.1 Climate zones of Australia (Source: BCA, 2003)



- Highlight challenges for the national housing industry with the release of new energy efficiency codes,
- Explore the technologies available to housing and sub-divisions for on-site electricity generation as a basis for the development of solar suburbs, including receptivity by electricity supply companies,
- Develop a set of criteria for possible future tools to prioritise options for improving dwelling designs to bring their energy efficiency up to the desired standard,
- Investigate barriers to energy efficient innovation, primarily because of disconnection between 'housing technology' and 'sub-division technology'.

1.2 Project Partners

The partners involved in this research project were:

CSIRO Manufacturing and Infrastructure Technology

Queensland University of Technology

Queensland Department of Public Works

Brookwater

1.3 Key Assumption

The key assumption behind this research is that there is an expanding market for information on energy efficient sub-divisional and building practices. As energy efficiency regulations increase, this need will grow and create significant demand for information on available assessment tools for creating sustainable sub-divisional layouts (orientation, solar access and the like), rating energy efficient designs and products that deliver energy efficiency (solar technology).

1.4 Report Structure

This report focuses on Phase Two of the project. The next chapter provides a background for the overall project and summarises the main issues arising from Phase One that will be examined in further detail throughout Phase Two. Chapter Three outlines the methodology, project parameters and management. Following this, Phase Two is presented in three studies;

- Chapter 4 – Energy Efficiency Rating (EER) Tool Study;
- Chapter 5 – Lot Rating Tool Study;
- Chapter 6 – On site Energy Generation Study.

Chapter 7 consolidates the conclusions from the Studies and outlines the criteria for possible future tools that will enhance the capability to provide options for improving energy efficiency of dwellings in a sub-divisional at the rating stage. This Chapter also examines the next steps for this project.

2. BACKGROUND

Australia's current pattern of residential development is resulting in urban sprawl and highlights the necessity for development to be sustainable to avoid unnecessary demand on natural resources and to prevent environmental degradation and to safeguard the environment for future generations. This becomes more apparent when noting facts such as:

- Australia's per capita consumption of space (floor space, private open space), energy and water rank among the highest in the world and are continuing to increase;
- Australia's per capita waste streams rank among the world's highest; and
- Australia's metropolitan planning and development strategies deliver poor environmental outcomes in relation to energy production and consumption and CO_2 emissions, with rapid growth in transport vehicle kilometres travelled and closed mind to distributed energy/solar suburbs[1].

2.1 New Dwellings

There are an increasing percentage of new dwellings undergoing construction. Data from the Australian Bureau of Statistics (ABS) shows that the seasonally adjusted number of Australian dwellings units approved increased from -6.5 % in September 2001-2002 (ABS, 2003a) to +26 % (September 2002 to 2003). This totals 175,135 new dwelling units (ABS, 2002). In addition, Australia's growth in housing stocks is outstripping its population growth. The average household size is decreasing, but Australians are living in larger dwellings, either in terms of new house size or in extensions to older dwellings (AGO, 1999b).

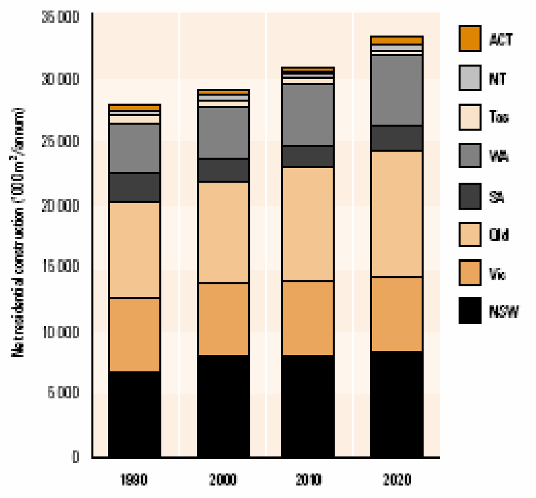
Queensland is Australia's fastest growing state. The December 2003 population of 3.84 million is projected to grow to 5.3 million in 25 years, reaching 6.5 million in 50 years (DLGP, 2004). In Queensland, in 2002-03, the number of dwelling units approved increased by 10.6 % on the previous financial year to 39,347. This highlights the dramatic growth in housing trends in Queensland and according to the Australian Greenhouse Office (AGO); this trend is projected to continue beyond 2020, as shown in Table 2.1.

Table 2.1 New residential construction

Net new construction ('000m²/annum)				
State	1990	2000	2010	2020
NSW	6 506	7 959	8 051	8 122
Vic	6 022	5 836	5 740	5 983
Qld	7 617	7 829	9 095	10 155
SA	2 047	1 922	1 848	1 996
WA	4 051	4 095	4 770	5 452
Tas	722	415	354	259
NT	228	284	333	382
ACT	467	492	523	577
Total	27 660	28 833	30 714	32 926

Source: (AGO, 1999b)

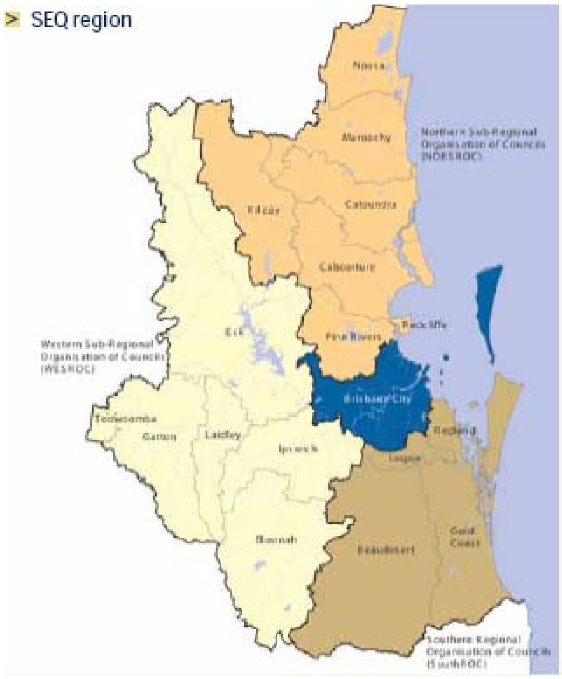
Figure 2.1 New residential construction trends



[1] As outlined in the CRC-CI Project Agreement No. 2002-063-B, *Sustainable Sub-divisions – Energy Efficiency*

Queensland's Department of Local Government and Planning (DLGP) advises that the annual demand for housing is predicted to increase by 6,400 dwellings to 41,500 annually over the next five years, resulting in the total number of households in Queensland increasing from 1,275,000 to 2,212,000 by 2026 (DLGP, 2004). Much of the growth concentrated in SEQ, with 17,719 new dwelling units alone, located in Brisbane (ABS, 2003b). The SEQ region comprises some eighteen local governments and has experienced high and sustained population growth since the 1980s, growing at an average of 55,000 persons each year between 1986 and 2003.

Figure 2.2 South East Queensland



Source: (Office of Urban Management, 2004)

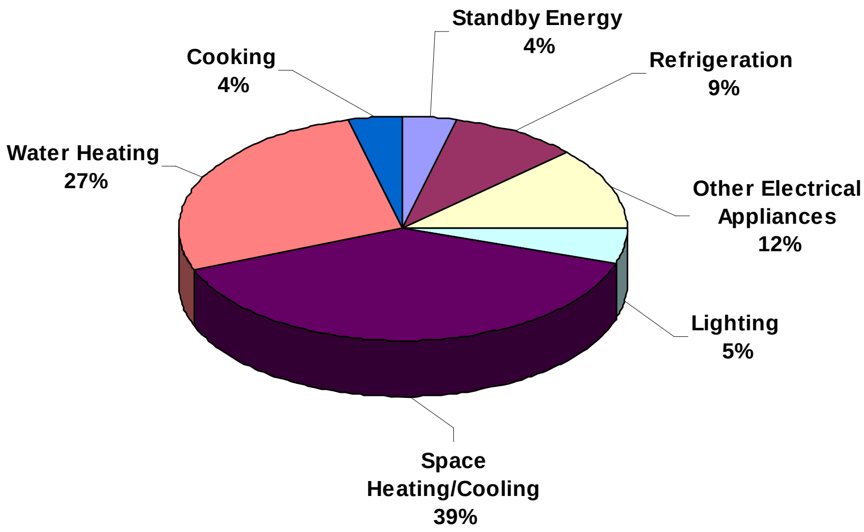
The estimated resident population of the region in 2004 is 2,654,000. Current projections for the region are 3,709,000 by 2026, an increase of around 1.05 million people, or almost 50,000 each year on average. The projected population increase, combined with the continuing trend towards smaller households, will require an estimated 550,000 new dwellings to be constructed in the region between 2004 and 2026. There will also be a greater demand for a diversity of housing forms to match the needs of changing household structures, particularly an increase in one and two person households across all adult ages (Office of Urban Management, 2004).

2.2 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 (CO_2), the main greenhouse gas, per year (Reardon, 2001).

Figure 2.3 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.

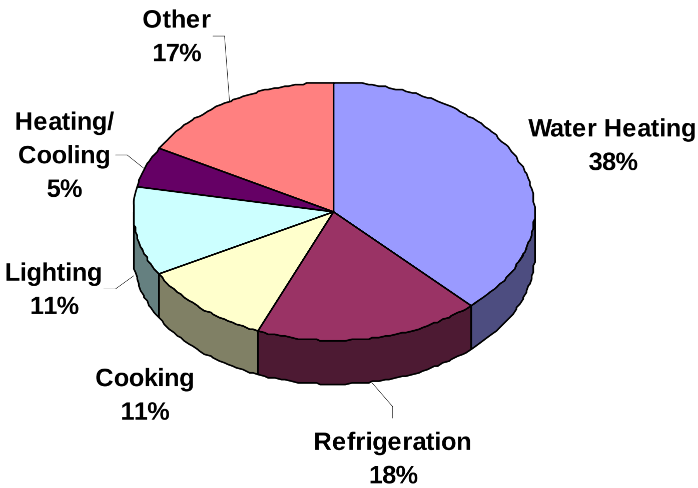
Figure 2.3 Average energy use in Australian dwellings



Source: (Reardon, 2001)

The breakdown of energy use in Queensland is, however, quite different with the amount used for heating and cooling being significantly lower. Figure 2.4 shows that heating and cooling energy accounts for only 5 % of the total, compared with 39 % as the Australian average. This difference is mainly due to the temperate climate of Brisbane where the need for conditioned spaces is minimal. However, this percentage is set to increase dramatically with the rapid increase in the number of air-conditioned dwellings in Queensland.

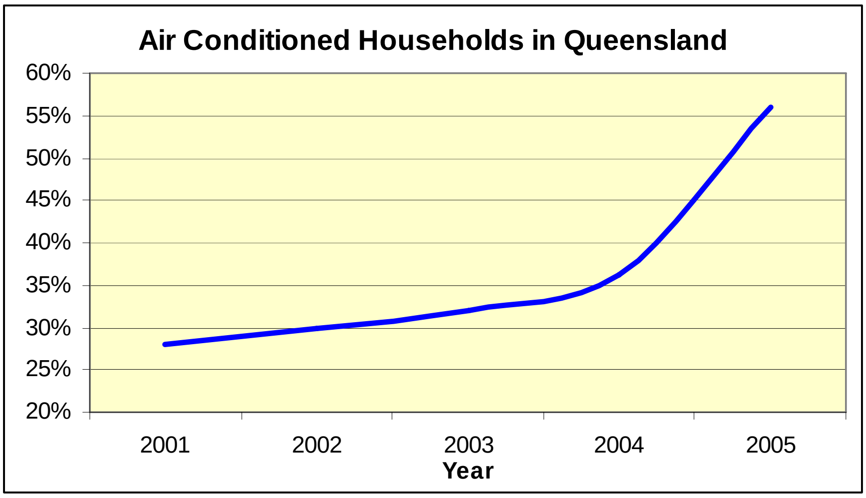
Figure 2.4 Queensland Household Energy Use



Source: (Queensland Conservation Council, 2004)

Figure 2.4 shows that in 2001 around 28 % of dwellings were air-conditioned, but this has increased to 36 % in 2004 and is expected to rise to 56 % by May 2005 (Mickel, 2004). Climatically inappropriate design is one factor behind this increase. Not only will such an increase see cooling energy become more dominant, but it will also place increased stress on the existing power generation and distribution network. In fact, it has been estimated that for every new air-conditioner installed it costs the state about $13,000 to keep it running. This cost takes into consideration the cost of generation as well as distribution upgrades and augmentation (Mickel, 2004).

Figure 2.5 Air-conditioned households in Queensland



Source: (Mickel, 2004)

Figure 2.4 also shows that water heating is the major energy use in Queensland households, accounting for 38 % of the total. This figure could be significantly reduced with the widespread adoption of solar hot water systems, which in Queensland are able to deliver up to 90 % of a household's hot water requirements without the need for fossil fuel energy.

2.3 Phase One Overview

The following summarises the main issues affecting sub-division layout to emerge from Phase One that will be examined in further detail throughout Phase Two. These include design for solar access, topography, lot size, lot orientation and sub-divisional densities. Further detail of Phase One can be found in the report from that Phase 'Benchmarking the Practices, Perceptions and Design of Sustainable Sub-divisions'.

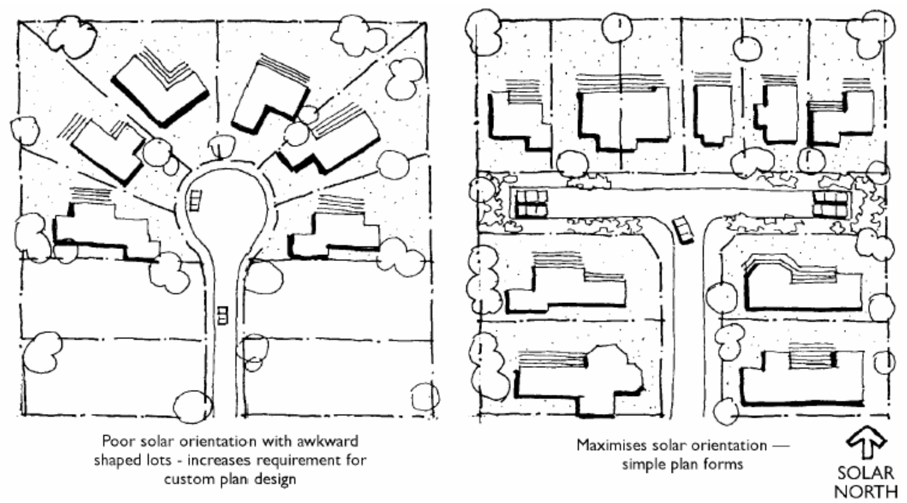
2.3.1 Sub-division design for solar access

Solar access in sub-division design is about manipulating the key variables of aspect, shape and density in combination with site characteristics such as topography and slope to achieve an optimum mix of lot sizes that are appropriately oriented for energy efficiencies. The characteristics of a sub-division correlate with good solar access for new housing. Effective energy efficient sub-division will passively direct that an overall development is significantly more energy efficient than conventional development. When lots are correctly aligned and proportioned, individual energy efficient housing can be provided with comparatively less effort due to suitability of the lot to site a dwelling with good solar access.

A sub-division design needs to maximise and protect solar access for each dwelling. Thus, consideration needs to be given to the basics – orientation, shape, size and width of the lot, solar setbacks and building heights.

The very essence of a solar suburb is one that maximises the percentage of dwelling lots having good solar access, which in turn facilitates the design of energy efficient homes. Solar suburbs consist of solar easements that use a hammer-head layout (see Figure 2.6) to have all lots with appropriate solar access as opposed to the poor solar orientation that is inevitable in cul-de-sac layouts.

Figure 2.6 Maximising solar orientation in sub-divisions



Source: (AMCORD, 1995)

2.3.2 Topography

Yield is the most important driver when configuring lots within a development site. One of the physical elements of a site most influential on yield is the terrain, which will present environmental and engineering constraints unique to each sub-division development Topography can dictate the development layout and due to this, areas having gradual terrain are seen as more desirable to develop. The steeper the topography, the more constraints the site will impose on the style and form of development that can occur.

Ideally, the areas dedicated for sub-division will have little slope, necessitating little cut-and-fill to create for a level dwelling pad to be positioned on the lot. Steep gradients will limit the type, size and orientation of home that can be constructed within a lot. Much of the steep topography not compatible for construction and is suited only for landscaping. As a result, small lots with steep terrain are not easy to build on. As one key informant acknowledged: 'If the topography is steep, the allotment needs to be at least 600-700m² as you cannot use a lot of the site'.

2.3.3 Lot orientation

As this research is looking to energy efficiency, it was common for key informants to associate orientation with solar access requirements. In Queensland, orientation for solar access to panels is not as pertinent as in southern states and the overriding solution to control indoor climates is via air conditioning, especially in project homes. Little connectivity was made with orientation to take advantage of natural light penetration and natural ventilation into homes.

2.3.4 Lot size

Lot size is not only closely associated to the investors' financial viability factors but to different family types/sizes, the range of residential dwelling types available, locational factors as well as consumer expectations and affordability.

The residential market recognises that the family structure in Australia has changed from what was the typical family of two parents plus children. This has resulted in the provision of sub-divisions for a variety of dwelling sizes, suited to the shifting demographics and life phases. Whereas some Greenfield developments will only offer the 'family size lot' other developments will offer a mix of lot sizes suited to different family types. Market desirability is maintained by using a formula to ratio the mix of 'small'[2] and 'large'[3] lots, as it is imperative

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

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

that Greenfield developments are not perceived to be 'too dense' or 'cramped' by prospective residents. This occurs in particular when there is a need for higher yield to make a development economically viable, resulting in a higher proportion of smaller lots in traditionally large lot Greenfield developments.

Ordinarily the smaller lots in Greenfield development are targeted towards affordability for the first-home buyer and convenience for the sole-occupant market, while the larger lots are targeted to the family market, which predominantly consists of the second-plus[4] home purchaser or empty-nesters'[5] market.

Conversely, smaller lots in Brownfield and infill development are seen as appropriate for the family market. Playing into this is the location factor, with small lots being the trade-off for residents to be in close proximity to services and facilities. Regardless of family type, smaller lots are acceptable in the inner-city/suburbs, whereas they are not seen as desirable in outer suburbs or in fringe areas. Larger lots are expected in the outer suburbs and are cited as the main reason for choosing to live in that location.

2.3.5 Lot density

When discussing density within a development site, key informants identified problems with local authorities, from which they receive mixed messages. Overall, two themes emerged.

The first theme was that although the planning instrument outlining development for an area has the concept of low-density, regulatory bodies are increasingly insisting on greater densities. The second theme was that the local authority would want the developer to provide low-density development, but in conjunction with the provision of services at a level impossible to support with a low-density population. Balanced with this is the developer's knowledge that their reputation rests with prospective residents who do not want their suburb to look overly dense, but also expect infrastructure and close proximity to ongoing services.

2.3.6 Phase One summary

The market for information and tools that provide energy ratings and analysis of buildings is continuing to grow as owners, tenants and regulators seek more energy efficient products and product providers seek to create these products at the lowest cost. The key informants believe it is only a matter of time before momentum builds, and sustainable energy efficiency becomes the standard. To encourage this growth, the key informants highlighted the following issues:

- The 3.5 star rating for residential construction in SEQ can be simply met with no reliance on appropriate sub-division orientation. There is a need to meet a benchmark, so that developers can achieve a sustainable outcome without losing any competitive edge in the market;
- Other than the BCA DTS Provisions, there is no clear measure of how to achieve the necessary standard, or to meet increasing standards;
- Research and demonstration that new and innovative models of sustainable development are more affordable than traditional models of development;
- Collaboration between local authorities, agencies, landowners and developers to integrate and work together to a common goal and vision that is of benefit all parties;
- Tools that measure energy efficiency, apply across the whole of the industry, yet are site specific and take into account factors such as a broad range of construction materials, orientation, adjacent built forms, deciduous and evergreen vegetation, and how the home operates once occupied;

[4] They have owned a home previously and this is their second or later home purchase.

[5] These are parents who have adult children who no longer live with them.

- There is a need to disseminate information regarding sustainable energy efficiency into the consumer market as the industry will meet a market-driven demand;
- Regulations need to be uniform to retain the competitive nature of industry;
- Incentives highlight the importance of the practice and make it more attractive to the supplier and the homeowner;
- Recognition of sustainable practices by the valuation and financial industry to overcome the financial barrier to accessing sustainable energy efficiency.

3. METHODOLOGY

The brief for this project delineated the subject area as SEQ, focusing on Brisbane and the surrounding and expanding cities of Ipswich, the Gold Coast and the Sunshine Coast. The focus was to examine sub-divisional and building practices in an area that is presently undergoing rapid growth and the resultant sprawl of urban development. This growth highlights the necessity for sustainability in development.

3.1 Parameters

This research focuses on energy efficiency of sub-divisions by examining a range of contemporary dwelling types, such as:

- Detached single storey – slab on ground, elevated and pre-fabricated;
- Detached double storey and split level;
- Attached medium density multi-storey residential (2 or 3 level, walk up); and
- Attached high-density multi-storey residential (over 4 storeys).

The Project Agreement (Appendix A) included a fifth category, small house – small office (SOHO). However, throughout the course of the study, it became apparent that it was not practicable to separate what is essentially a small space within a dwelling, into a discrete category. Instead, this use has been identified and included in the thermal modelling for some of the following case studies.

3.2 Significance

The uniqueness of this project is in the:

- Connection of 'housing technology' to 'sub-division technology' in sustainable sub-divisions;
- Access to a new EER assessment tool which includes a more appropriate ventilation model;
- Advising industry and government on the adequacy of current design options in the context of an emerging energy code for medium and high-density dwellings.

While the focus of the project is energy efficiency of sub-divisions, solar access is only one aspect of energy efficient subdivisions and development. This project does not examine the following factors, which significantly affect dwelling and sub-division sustainability:

- Embodied energy of the materials used in construction of the dwellings;
- Operational energy of household appliances;
- The impact of occupant behaviour.

3.3 Methodology

The project methodology consists of the following activities:

In Phase One;

- Interviewing industry professionals who undertake sub-division activities;
- Conducting a workshop with building industry professionals from the private and public sectors within SEQ on the requirements of sub-divisions and the performance of current assessment tools;
- Preparing a project report.

In Phase Two:

- Identifying sub-divisions where dwellings in the identified types/categories will be constructed;
- Obtaining plans for an appropriate sample of dwellings;
- Assessing the case study dwellings against the new current standards;
- Comparing the results for the different dwelling types in sub-tropical climate zones;
- Developing criteria for possible future energy efficiency tools;
- Exploring the technologies available to housing and sub-divisions for on-site energy generation; and
- Preparing a project report.

3.4 Ethics

There are no distinctive ethics associated with this study.

The plans used throughout the report were restricted to those that could be provided by Project Partners. The housing developments that were to be made available for study by CRC members include:

- Kelvin Grove Medium density residential (Queensland Department of Public Works);
- Springfield residential (Springfield Land Corporation);
- Research House – Rockhampton (Queensland Department of Public Works);
- Pre fabricated dwelling (Delfin Lend Lease);
- High-rise apartment (Queensland Department of Housing on request from DPW).

Under the Partner Agreements, the provision of plans constitutes permission to use the plans and images for this project. In one instance, the Project Partners were unable to provide appropriate plans for medium density dwellings. Permission to use privately provided plans was obtained and is held by the CRC-CI.

3.5 Project Management

Throughout the project, Project Partners were involved and provided valuable input and feedback through a series of Project Team and individual meetings. These meetings included:

- Project Team Meeting1, 29th June 2004;
- Individual Partner Meeting 1, July 2004;
- Individual Partner Meeting 2, August 2004;
- Individual Partner Meeting 3, September 2004;
- Individual Partner Meeting 4, September 2004;
- Project Team Meeting 2, 30th September 2004. At this meeting, a draft case study was presented for comment.

4. ENERGY EFFICIENCY RATING TOOL STUDY

4.1 Introduction

This research focuses on the energy efficiency of sub-divisions by assessing a range of contemporary dwelling types, including:

- Detached single storey – slab on ground, elevated and pre-fabricated;
- Detached double storey;
- Medium density multi-storey residential (2 or 3 level, walk up);
- High-density multi-storey residential (over 4 levels of residential apartments).

This project does not examine the following factors, which significantly affect dwelling sustainability within the sub-divisions:

- The embodied energy of the materials used in construction of the dwellings;
- Operational energy of household appliances;
- The impact of variations in individual occupant behaviour.

4.2 Energy Efficient Dwellings

In Phase One of this project, energy efficient dwellings were defined as homes that through orientation, design, construction, materials, and choice of appliances, take advantage of the microclimate, especially solar access. Energy efficient dwellings should have lower demands on non-renewable energy sources, reduce the level of greenhouse gas emissions, and provide the occupants significant savings.

According to the key informants, the largest single contributor to energy efficiency is appropriate orientation. Appropriate orientation will capture natural light, breezes for cross-flow ventilation and solar access for energy. 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.

EER provisions for Class 1[6] dwellings were only introduced in Queensland in 2004 and the required level of 3.5 Stars is relatively easy to meet through Deemed to Satisfy (DTS) Provisions. Given the recency of this change, it would be illustrative to look at the history of dwelling efficiency measures in Australia and at the impact of introducing EERs in other states, specifically Victoria and the Australian Capital Territory (ACT), to examine future possible developments for EERs in Queensland.

4.2.1 History of building energy efficiency measures in Australia

The following history of building energy efficiency measures is drawn from a 1999 publication by CSIRO on behalf on the AGO and entitled 'Scoping Study of Minimum Energy Performance Requirements for Incorporation into the Building Code of Australia'.

> *There has been a long history of research and development in energy efficient building within Australia. The history of research into the impact of the building industry on greenhouse gas emissions is much shorter. The two areas are, of course, related in that the production and consumption of energy are major producers of greenhouse gas emissions (AGO, 1999b).*

The major events in the recent history of greenhouse gas and energy-related research in

[6] 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 fir resistant wall.

Australia up to 1999 were:

1984	Department of Housing and Construction energy targets;
1984	Five Star Design Rating Scheme for detached housing;
1991	Victoria introduced mandatory insulation requirements for residential buildings;
1992-93	Victoria developed the Victorian House Energy Rating Scheme (VicHERS) and point-score based scheme for house energy rating. Method was an alternative compliance path to insulation provisions;
1994-95	Nationwide House Energy Rating Scheme (NatHERS) developed;
1995	ACT House Energy Rating Scheme (ACTHERS) developed for ACT, based on VicHERS. New Class 1 building required to achieve 4 [7]Stars;
July 1995	Building Energy Code of Australia (BECA) first draft technical outline and rationale;
Nov 1997	Prime Minister's statement, 'Safeguarding the Future: Australia's Response to Climate Change;
Dec 1997	Kyoto Protocol;
1998	Building industry response to Prime Minister's statement through the creation of the Australian Building Energy Council (ABEC);
1999	Decision of Ministerial Council to work with industry on mandatory requirements;
March 1999	ACT - the Energy Efficiency Ratings (Sale of Premises) Act 1997 requires that all houses advertised for sale must have an EER (ACT PLA, 2003a);
1999	Energy Management Task Force agreed to fund development of a version of NatHERS for highly ventilated buildings in warm climates. (AGO, 1999b).

Major developments that have occurred since that report include:

2003	Australian Building Code Board (ABCB) introduces requirements (EER) for Class 1 and 10 buildings
Sept 2003	EER provisions for Class 1 buildings introduced in Queensland;
Jan 2004	ABCB proposes that similar requirements be applied to other residential buildings, including Class 2[8] buildings (ABCB, 2004b);
July 2004	Victoria requires 5 star energy efficiency standards on all new BCA Class 1 dwellings (Victorian Government, 2004);
July 2004	Victoria requires that all new Class 2 buildings in Victoria achieve an average house energy rating of at least 5 stars for all the dwellings in the building and a minimum house energy rating of at least 3 stars for each dwelling.

Major proposed future changes include:

July 2005	Victoria will require that all new BCA Class 1 dwellings be 5 Star energy efficiency, have water efficient fixtures and either a water tank or solar hot water system (Victorian Government, 2004);
2005	BCA is to include requirements for Class 2 dwellings (ABCB, 2004c).

[7] Star ratings are on a scale of 1 to 5, with 5 being the optimum rating

[8] BCA Class 2 – a building containing two or more sole occupancy units, each being a separate dwelling.

Two factors emerge from this history:

- Once EER provisions are adopted, they tend to increase either in rigour (Victoria) or in range (ACT); and
- A range of EER programs has emerged in response to the evolving regulatory framework – the EER programs mentioned above are just some of those that are in use throughout Australia.

EER provisions could be expected to increase in future in Queensland, so it is worthwhile examining these two factors in more detail.

4.2.2 Increasing impact of EERs in Victoria and the ACT

Victoria

In 1991 Victoria introduced mandatory insulation requirements for BCA Class 1 residential buildings (AGO, 1999b). These requirements consisted of attaining either DTS with specified minimum R values of insulation for roof or ceiling, external walls and ground floor, or House Energy Rating (HER) of at least 3 Star (Australian Greenhouse Office, 2000). The phrase R-value refers to the thermal resistance, which for a homogenous component, is calculated by dividing its thickness by its thermal conductivity. The total R-Value means the sum of the R-Values of the individual component layers in a composite element including the air space and associated surface resistances. Up until 2004, there were two options for demonstrating compliance with the requirements:

- DTS insulation provisions for ceilings (R2.2), walls (R1.3), and floors (R1), or
- HER of 3 Stars in VicHERS.

In 1994, the requirement for compliance was increased to 4 Stars, but this was reduced to 3 Stars in 1997. In 1999, a FirstRate analysis of 110 council plans from 1990 (pre-regulation) and 240 plans from 1999 found that:

> *The DTS Provisions of BCS 96 have delivered residential buildings with a state average rating of NatHERS 2.2 stars, although the performance goal is 3 stars. The insulation component of the Deemed-to-Satisfy Provisions has also permitted buildings with less than 1 Star rating to be constructed* (AGO, 1999b).

In July 2004, Victoria moved to requiring 5 star energy ratings on all new dwellings. There are three options available to builders to meet the requirements:

- 5 Star energy rating for the building fabric; or
- 4 Star rating for the building fabric plus water efficient fixtures and a rain water tank, or
- 4 Star energy rating for building fabric and water efficient fixtures and a solar hot water system.

From July 2005, all new dwellings will have to be 5 Star energy efficiency, have water efficient fixtures and either a water tank or solar hot water system (Victorian Government, 2004).

Victoria has also introduced regulations for Class 2 dwellings. From July 2004, all new Class 2 buildings in Victoria must:

- Achieve an average house energy rating of at least 5 stars for all the dwellings in the building and a minimum house energy rating of 3 stars for each dwelling in the building as assessed by a person accredited in the use of either the FirstRate or NatHERS software;
- Comply with Practice Note 2004-55.

In just over ten years, Victoria has moved from introducing EER requirements that were relatively easy to meet, such as those recently introduced in Queensland, to requiring the maximum EER for all new dwellings. Victoria has recently also moved to introducing EER requirements for Class 2 dwellings. Other states could be expected to follow a similar trend.

ACT

From 1995, new Class 1 buildings in the ACT were to achieve 4 Stars with the assessment carried out by an accredited assessor using ACTHERS. Roofs must have R3 insulation in the ceiling space or R2 in an exposed raked ceiling. External walls must have R1.5 insulation. The floor must either be concrete or have a total R-value of 1 including the carpet. In the ACT, the R value is for the added insulation to the roof and wall and not the total R value of the element (AGO, 2000b).

- In 1999, the AGO 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).

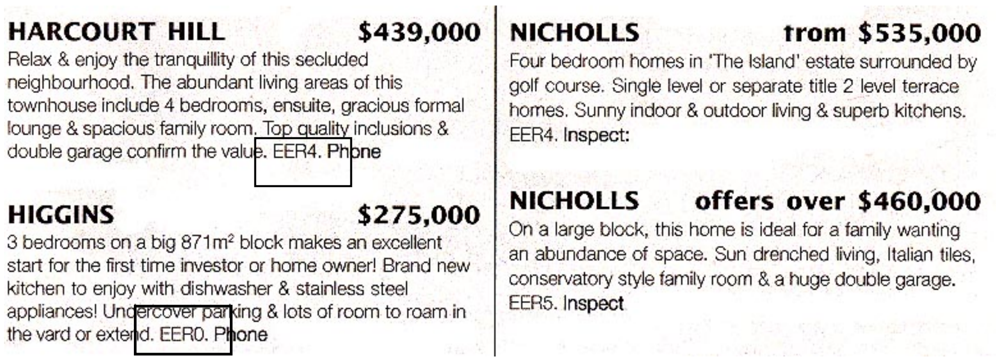
Additionally;

> *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)

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. 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 ACTHERS Energy Rating Report to purchasers prior to entering into a contract for sale. (ACT PLA, 2003a).

There is anecdotal evidence to suggest that the presence of EER in property guides over the last few years, as shown in Figure 4.1, has heightened awareness among the owners of the 80 % of the residential market that is unaffected by increasing EER provisions in new dwellings.

Figure 4.1 ACT Property Guide, 2003


HARCOURT HILL **$439,000**
Relax & enjoy the tranquillity of this secluded neighbourhood. The abundant living areas of this townhouse include 4 bedrooms, ensuite, gracious formal lounge & spacious family room. Top quality inclusions & double garage confirm the value. EER4. Phone

HIGGINS **$275,000**
3 bedrooms on a big 871m² block makes an excellent start for the first time investor or home owner! Brand new kitchen to enjoy with dishwasher & stainless steel appliances! Undercover parking & lots of room to roam in the yard or extend. EER0. Phone

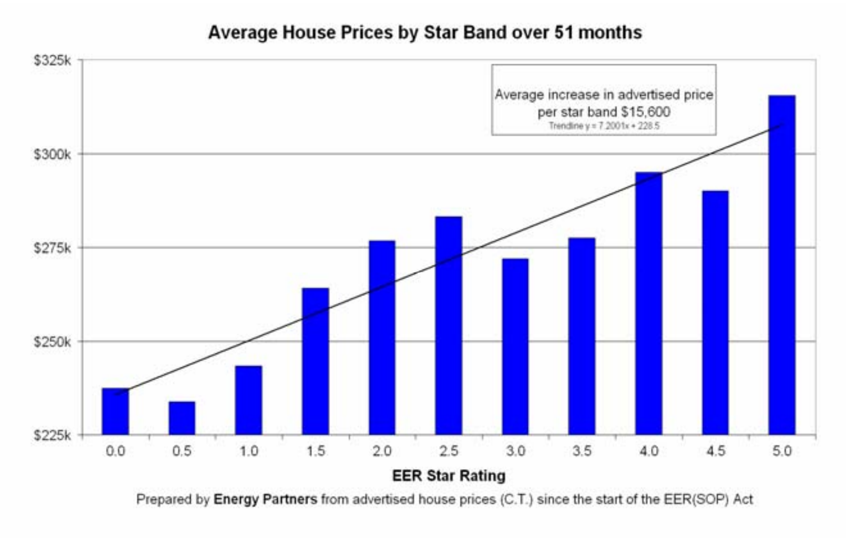
NICHOLLS **from $535,000**
Four bedroom homes in 'The Island' estate surrounded by golf course. Single level or separate title 2 level terrace homes. Sunny indoor & outdoor living & superb kitchens. EER4. Inspect:

NICHOLLS **offers over $460,000**
On a large block, this home is ideal for a family wanting an abundance of space. Sun drenched living, Italian tiles, conservatory style family room & a huge double garage. EER5. Inspect

Source: (Canberra Times, 2003)

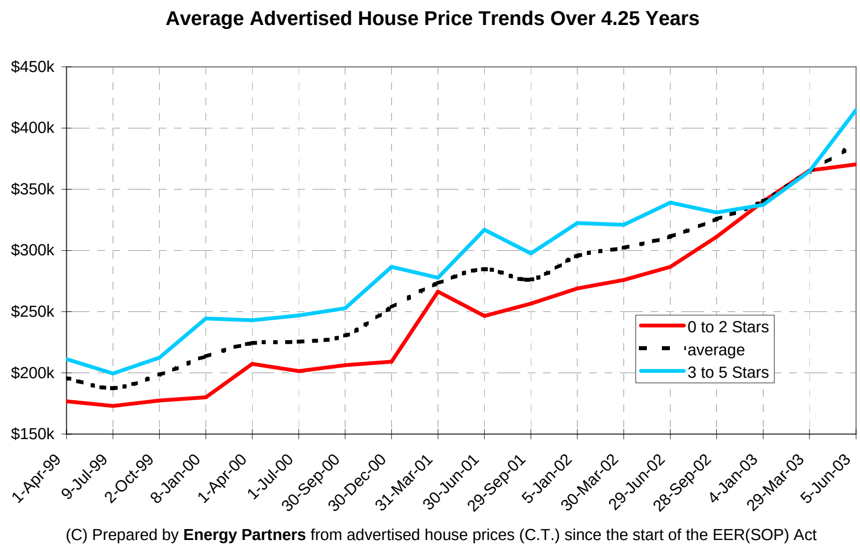
An ACT firm has been recording the price, location and energy rating of dwellings advertised for sale in the ACT over the last four years and has concluded that there is a clear market preference for energy efficient dwellings.

Figure 4.2 ACT average house price by star band



Source: (Energy Partners, 2003)

Figure 4.3 Average advertised house price trends



Source: (Energy Partners, 2003)

Figure 4.2 shows that:

- 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 clear market preference for energy efficient dwellings.

Two factors need to be considered in relation to the findings. One is that larger houses tend to achieve higher prices and secondly, at present it is easier for larger houses to achieve a higher star band score as current thermal simulation tools favour large floor areas (Energy Partners, 2004). It is expected that these trends will be moderated somewhat when new versions of the thermal programs adjust the large area bias, but that the overall trend for higher rating dwellings will remain. It would seem reasonable to assume that this trend could lead to a greater consumer awareness of EER tools and to increasing pressure on the accuracy of the tools. For this reason, it is important to have an understanding both the role and the limitations of EER tools.

4.2.3 EER tools – roles and limitations

House Energy Rating Schemes (HERS) are being introduced throughout Australia. The aim is to reduce residential energy consumption and increase thermal comfort by encouraging improved building envelope design. However, the staged adoption of these requirements has led to a variety of standards and tools throughout Australia. This has led to variations within and across states and to confusion and complexity within the building industry.

The following section outlines some of the thermal simulation tools currently in use in Queensland:

- CHENATH is the core simulation engine developed by CSIRO for Australian climates and modelling systems are based on it, including NatHERS, FirstRate and Quick Rate, BERS, Q Rate and ACTHERS. NatHERS and BERS run CHENATH directly (with different user interfaces), while the others use correlations derived from many thousands of CHENATH runs to obtain their results. AccuRate uses a greatly enhanced version of CHENATH and has a new user interface;
- NatHERS is currently the most commonly used. It has been widely tested, calibrated and verified to provide consistent results for most climate zones. A national testing protocol will allow other tools to be calibrated and verified to the same standards.

Among the currently available programs, 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 and this is the focus of the newer software, called AccuRate.

The development of AccuRate is being managed by the AGO, which, in its 2003-2004 Annual Report noted;

> *Work also continued on upgrading the Nationwide House Energy Rating Scheme (NatHERS) to cover a wide range of residential building types in all Australian climate zones. The revised house energy rating software tool, AccuRate, which improves on NatHERS by better modelling ventilation, will be extensively tested before its public release. AccuRate will allow more comprehensive and consistent analysis to help building designers improve the thermal performance of residential buildings, lowering greenhouse gas emissions and increasing householder comfort* (Commonwealth of Australia, 2004).

The results of this project will inform the further testing and refinement of AccuRate.

All the rating programs are designed to rate the thermal efficiency of the building envelope using predefined thermostat and heating/cooling cycle settings. The tools are not designed to predict actual energy usage of a specific dwelling and consequently the thermal programs do not allow for individual occupancy patterns, which result in individuals accepting a different range of temperatures before introducing either heating or cooling equipment. The programs also do not allow for regional lifestyle preferences, such as a preference for open windows, even on occasions when the outside temperature is higher than that inside. The tools do allow for acclimatisation to the extent that the cooling thermostat setting is set to the 'neutral' temperature, which in turn depends on the climate. The newer software does allow for these preferences to the extent that the outdoor temperature can be higher than indoors and the windows will still be opened if the air speed with open windows is high enough for its cooling effect to outweigh the difference.

Heating and cooling energy requirements form a significant proportion of total household energy consumption in most climates. However, in well-designed buildings in more benign climates like SEQ, heating and cooling energy share can be low. It is important to note that thermal tools assume that both heating and cooling will be used to moderate internal temperatures whenever they are outside a comfort band. This assumption can be misleading where mechanical cooling is not used.

Hot water heating is often the largest single energy user in these climates. Energy rating tools do not include energy used for heating water. The embodied energy content of building materials can also be significant over the lifetime of the building. (Reardon, 2001). However, embodied energy is not factored into thermal simulation tools that test the performance of the building envelope.

4.3 Energy Efficient Dwellings in Queensland

EER provisions for Class 1 buildings were introduced in Queensland on 1 September 2003. In Phase One, key informants noted that there is no appropriate tool with which to measure sustainability. They also noted that the 3.5 star rating for residential construction in SEQ could be simply met with no reliance on appropriate sub-division orientation. Even so, all key informants discussed the need to meet a criterion, or the need for a benchmark, so they know how to achieve a sustainable outcome without losing any competitive edge in the market. A tool is needed that can measure design options of elements such as orientation, natural ventilation and light. A rating is necessary so that all players can understand what ‘sustainability’ covers, and how to measure it, within the level playing field of industry. At present, other than the BCA DTS Provisions, there is no clear measure of how to achieve the necessary standard, or to meet increasing standards.

Queensland also has different construction methods that are often considered better suited to the sub-tropical climate and there is ongoing concern that the current 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 focuses on SEQ as that area is undergoing significant growth. This study will examine a range of dwellings types that commonly occur in new developments in SEQ to provide a snapshot of the energy efficiencies using the tools currently available, or proposed for SEQ.

4.3.1 Comparison of the EER tools in SEQ

In the development version of AccuRate, it was possible to run a simulation using the NatHERS ventilation model instead of AccuRate’s own ventilation model. The NatHERS ventilation model makes some provision for ventilation, but is far less detailed than AccuRate’s ventilation model. NatHERS provides a benchmark for comparison with BERS and AccuRate, which progressively improve the ventilation modelling.

In some instances, the dwellings had already been modelled by an external assessor using either BERS or FirstRate. The ratings data was made available for this study, but as the data files were not provided, further testing, such as increasing the external shielding or altering the orientation was not possible.

BERS was designed to test the annual thermal performance of Class 1 dwellings only and consequently BERS was not used to examine the Class 2 dwellings. As a result, the program comparisons for the Class 2 dwellings are between NATHERS and AccuRate ventilation models.

4.3.2 Star rating ‘to be confirmed’

The present Star Band settings cover a range of 1-5 stars with 5 being the highest and optimum level. The star band settings are derived from the annual total energy load as follows:

Table 4.1 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

One of the aims of AccuRate is to remove the 'bias' toward large houses 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 a small house. Corrections developed by the AGO will be incorporated into AccuRate;

- Dwellings with an internal floor area below 200 m^2, have the MJ/m^2 adjusted downward;

- Dwellings with an internal floor area above 200 m^2 have the MJ/m^2 adjusted upward.This correction will be applied after the energy loads have been calculated and will appear on the ratings report as the Area Adjusted Star Band Score and this Score will determine the final star rating of the dwelling, using Band Width data supplied by the Australian Greenhouse Office (AGO). At present, there are calibration issues still to be resolved with the Area Adjustment Band Score Thresholds. As a result, this study will discuss the dwelling ratings in terms of MJ/m^2/annum and not in terms of star ratings, which will be noted as 'to be confirmed' (TBC).

The absence of the area adjusted star ratings makes it difficult to determine what constitutes a significant variation. A significant variation in annual total load could be considered as a variation that causes the star band score to alter by ±½ Star. This has added an unexpected degree of difficulty in interpreting the data and has led to the need to include more detail in each case study in place of a 1-5 star indicator. The point of comparison then must lie within the simulations run for each dwelling and in the totals between the case studies.

4.4 Case Study Selection

As stated earlier, the objective of these case studies is to provide a snapshot of the EER of a range of dwellings types that commonly occur in new developments in SEQ. The case study dwellings are intended to represent a range of contemporary dwelling types, rather than focusing on specific dwellings. These types fall into two broad categories, detached and attached, and include:

- Detached single storey – slab on ground, elevated and pre-fabricated;
- Detached double storey and split level;
- Attached medium density multi-storey residential (2 or 3 level, walk up); and
- Attached high-density multi-storey residential (over 4 storeys).

A fifth category, small house – small office (SOHO) was originally identified, however, throughout the course of the study, it became apparent that it was not practicable to separate what is essentially a small space within a dwelling, into a discreet category. Instead, this use has been identified and included in the thermal modelling in some of the following case studies.

The case study selection was limited to plans that could be provided by Project Partners. The Project Brief delineated SEQ as the study area, however in some instances the plans provided referred to dwellings located outside the case study area. To retain the appropriate focus and to eliminate variations based on differing climatic conditions, all detached dwellings are modelled as if located at Springfield (Climate Zone 9).

Springfield is an outer suburban Greenfield development of 2860 hectares located 23 kilometres from the Brisbane Central Business District (CBD). The development started in 1992 and is expected to house some 60,000 residents within 20 years.

The medium and high-density dwellings are modelled as if located in the Kelvin Grove Urban Village (KGUV) (Climate Zone 10). The KGUV is an inner urban Brownfield development comprising some 16 hectares and located 2 kilometres from the Brisbane CBD. This development was launched in 2002 and is expected to house some 800 residential units over the next six years.

After an examination of the individual case studies, the main findings will be summarised to address the issues arising from the lot rating tool study. These are topography, orientation, lot size and density. It is expected that the criteria for future tools that link sub-division and dwelling design will emerge from this study.

4.4.1 Presentation of the case study dwellings

In Phase One, the key informants commonly described both the lots and dwellings according to size with a small lot being defined as less than 450m², or less than 15 metres wide, and large lots as over 560m². A small dwelling was less than 200m² internal floor space, which may include a garage, but excludes balconies, pergolas and the like. Appendix C has a detailed examination of each case of the following case study dwellings. The images have been proportionally reduced to suit page layout and are not to scale. Dimensions have not been included.

Modelling assumptions

In order for the EER assessments to be carried out on the case study dwellings, it was necessary for a number of assumptions to be made about the dwelling construction and operation. Some of these construction assumptions are built into the software and vary between the programs used. Other assumptions arose because the level of data required for the program simulations was not discernable from the plans supplied and time precluded individual discussions with the designers to clarify exact construction details. The assumptions made for each dwelling are detailed in Appendix C.

User behaviour

The user behaviour assumptions outlined above are built into the software and cannot be varied for rating purposes. These behaviours do not necessarily reflect common household patterns and also make no allowance for differences between weekday and weekend use. As the performance of the building envelope is being assessed, there is also no allowance for lighting and appliance use (Energy Efficient Strategies, 2002).

Conditioned floor space comparisons

The aim of comparing the floor areas is to determine the variations in conditioned floor areas that result from the zoning characteristics and from the different data entry methods. These differences affect the thermal performance of the dwelling. The focus was on establishing the percentage of conditioned floor area to allow the impact of these variations to be considered. No attempt was made to ensure that the percentage of conditioned floor area was similar in both programs.

The conditioned floor area for the dwelling appears on the EER assessment statement.

Assessing the impact of orientation on energy efficiency

The Lot Rating Tool Study is assessing the appropriateness of the lot-rating tool developed by the Sustainable Energy Development Authority (SEDA) for SEQ. To inform this Study, both the detached and attached dwellings were modelled throughout 360° at 45° increments to assess the impact of orientation on the energy load.

Assessing the impact of increased shielding on energy efficiency

The Project Brief focused on examining orientation; however, the need to include shielding simulations was triggered by the following issues;

- The Phase One key informants identification of increasing densities in Greenfield developments; coupled with
- Consideration of the high percentage of small lots in lot rating case study 1.

In BERS, the ventilation selection, terrain type and the wind speed data from the climate file, determines the number of air changes per hour that are possible when the windows, doors and other adjustable vents are opened. The ventilation selection relates to the cross ventilation potential for cooling in hot weather and the 'terrain type' determines the attenuation of the wind about the building. This may be due to other buildings and obstacles as well as landforms, which cause wind shadows or funnel the wind towards the building.

The BERS assessor can select from the following terrain types:

- Exposed;
- Open;
- Suburban;
- Protected.

In AccuRate, the position of each external opening is entered and the program calculates the internal cross ventilation capacity. The external shielding selection follows:

- 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-city housing.

In a suburban setting, increased densities, zero lot coverage, high, solid fencing, close and dense foliage or high retaining walls all combine to reduce natural ventilation. Modelling the impact of increasing external shielding is the 'flip side' of developing a more sophisticated software package that allows for increased ventilation.

Determining the shielding is a matter of judgement based on the assessors' knowledge of local conditions, as detailed information is rarely available at the time of assessment. This portion of the study was outside the original intent of the project and so the number of simulations, such as examining the combined impact of a combination of increased shielding and altering the orientation, had to be limited.

4.5 Detached Dwellings

> *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)*.*

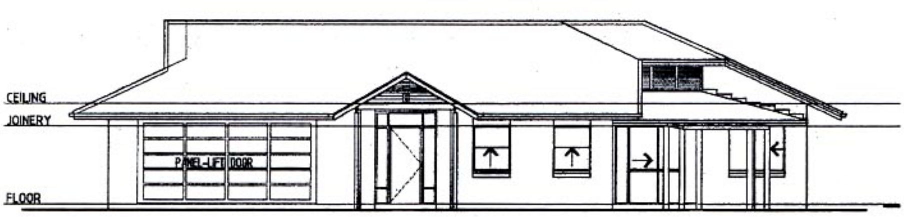
This cautionary note from the AGO serves to introduce the individual dwellings. A number of dwellings have been constructed recently to provide benchmarks for safe and sustainable sub-tropical dwellings. Of these, Research House, Rockhampton, a research and demonstration dwelling and one of the Greensmart Homes, Springfield, a demonstration dwelling, were included in this study. Both were designed to take advantage of passive design.

The energy loads achieved for both case studies for this project will differ from that achieved for both as actually constructed. Research House was modelled as if located at Springfield and its performance there could be expected to vary as a result. However, this 'relocation' enables its performance to be compared directly with that of the other dwellings. The plans provided for the Greensmart dwelling came from an early phase in the design development process and differ from the constructed dwelling, which has additional ventilation features in the main living area.

The individual dwellings are expected to provide a benchmark for comparison with the project homes – or highlight the challenges for the ongoing relationship between sub-tropical designs and southern-based thermal simulation tools.

A.1.1 Case study 1 - individual dwelling (Research House)

Figure 4.4 Case study 1



- Single storey, flyash veneer on slab, metal roof – remaining elevations and plans for this and all the case studies are at Appendix C.
- Large (220 m² internal space) 4 bedroom (or 3 bedroom + SOHO), 2 pedestal;
- Designed for traditional flat or cut and fill lots.

Case study 1 focused on the need for the thermal tools to adapt to the materials and design decisions that arise from these demonstration and research dwellings. This case study also introduced the differences in zoning regimes between BERS and AccuRate and examined the potential for influencing the energy loads, and star ratings, through manipulating the conditioned floor areas by altering the zone type.

Table 4.2 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	19.1	150.2	169.1	
BERS	Not available	Not available	Not available	5.0
AccuRate	21.0	86.6	107.7	

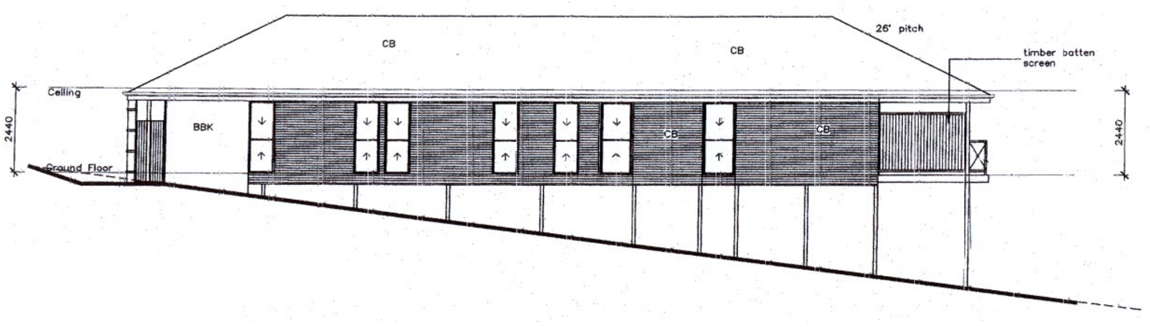
This dwelling has a highly ventilated roof space. The ventilation features are operable and are expected to used only in hot weather. The ventilation of this space could be expected to exceed the level of ventilation allowed for in AccuRate. As a result, the cooling and total energy loads in Table 1.1 may be conservative.

Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling with the newer software has resulted in a decrease of 37 % in the annual total load between NatHERS and AccuRate;
- In AccuRate, altering the orientation resulted in an increase in annual total load of 10 % above the optimum level to a total of 107.9 MJ/m²/annum for the worst orientation;
- The optimum and worst orientations were in the range predicted by the SEDA lot rating tool;
- At the presented orientation, increasing the external shielding from suburban to heavy in AccuRate resulted in an increase of 5 % in the annual total energy load to 113.0 MJ/m²/annum. This exceeds the total achieved by altering the orientation alone;
- Manipulating the conditioned floor area has potential for reducing the overall energy performance of the dwelling and increasing the EER.

4.5.1 Case study 2 - individual dwelling (Greensmart Home)

Figure 4.5 Case study 2



- Small lot size (332 m²) with 1 star lot rating;
- Single storey, lightweight clad and brick veneer on an elevated slab, metal roof;
- Small (150 m²) 3 bedroom, 2 pedestal;
- Designed for small, steeply sloping lots;
- Sub-floor area to be enclosed with battens (not shown above).

In case study 2, the total conditioned floor area, percentage of conditioned floor area and the rooms that comprise these totals were similar for all programs. Therefore, any variations in the energy loads must arise from variations in the constructions and/or variations in the simulation engines.

Table 4.3 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	43.6	152.9	196.4	
BERS Slate or tiled suspended slab No bulk insulation	30.5	177.1	207.5	1.5
BERS Suspended slab insulation (additional) R1.5	19.0	87.1	106.1	3.5
AccuRate AAC 75mm - total R1.5.	43.9	89.1	133.0	

Constructions emerged as an issue for this case study as there were significant differences in the way the programs handled the flooring material, which is Hebel Power Panel. This material is not offered in either program at present, but it can be approximated in AccuRate. The range of EERs achieved by the external assessor highlight the need for thermal programs to adapt to the materials and design decisions that arise from benchmark dwellings.

The battens used in the garage door and in the sub-floor area (not shown on the elevation above) cannot be constructed in AccuRate in a manner that includes a permanent degree of openness. While the sub-floor area can be set as being open, battens may provide a higher degree of ventilation than calculated in AccuRate. This could be expected to impact on both the heating and cooling loads. This issue is examined in further detail in case study 8.

Combining sub-division and dwelling performance, the main findings from this case study were:

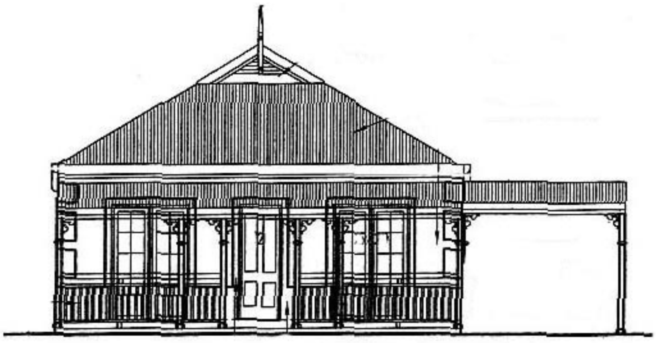
- Improved ventilation modelling with the newer software has resulted in a decrease of 32 % in the annual total load between NatHERS and AccuRate;

- Altering the orientation in AccuRate resulted in an increase in the annual total load 18 % above the optimum level to a total of 154.1 MJ/m²/annum for the worst orientation;
- The optimum and worst orientations are in the range predicted by the SEDA lot rating tool;
- At the presented orientation, increasing the external shielding from suburban to heavy resulted in an increase of 11 % in the annual total energy load to 148.7 MJ/m²/annum;
- With increased external shielding the annual total load is similar range to that achieved by altering the orientation alone;
- The worst case scenario, that is with the dwelling sited to conform to a sub-divisional layout that is inappropriate for the design in conjunction with heavy external shielding causes an increase of 40 MJ/m²/annum, or some 30 % to a total of 173.6 MJ/m²/annum.
- Finally, reducing the insulation levels to DTS levels was not explored, yet this would be a legal option for any homeowner optioning a demonstration dwelling to suit their requirements.

4.5.2 Case study 3 - project home

This type of dwelling is becoming more common in new developments in SEQ as developers increase the ratio of small and large lots.

Figure 4.6 Case study 3



- Small lot (300m²), 4 star lot rating;
- Single storey brick veneer on slab, metal roof;
- Small (104m²), 3 bedroom, 1 pedestal.

There are no unusual constructions associated with this dwelling. The conditioned floor areas, and the rooms comprising the total areas, are similar in all programs. Combined with the standard constructions, this means that any variations in the energy loads must arise from differences between the thermal programs.

Table 4.4 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Complete program	40.2	164.2	205	1.5
NatHERS Simple ventilation	17.0	125.1	142.1	
BERS	29.8	109.8	139.6	3.0
AccuRate	17.3	97.4	114.8	

Modelling the dwellings in the complete version of the NatHERS program was outside the scope of this project but has been undertaken for selected case studies to highlight the improvement in energy efficiency modelling.

Table 4.4 shows the significant drop in the cooling and total loads expected when first BERS and then AccuRate make more allowance for natural ventilation

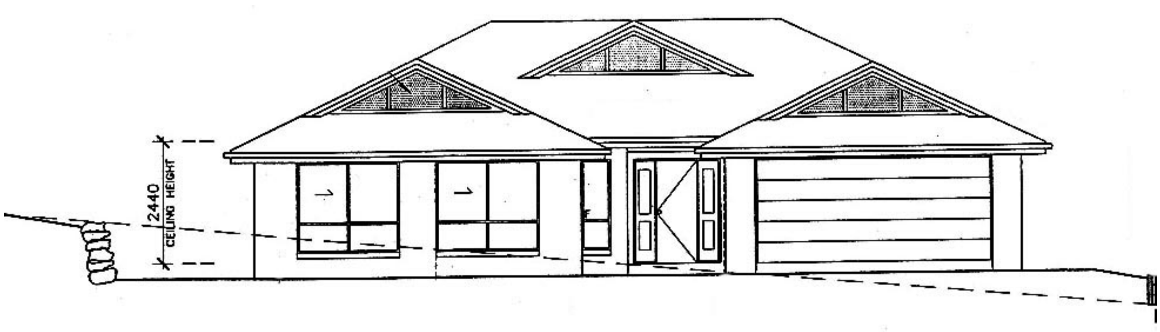
Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling has resulted in a decrease of 20 % in the annual total load between NatHERS and AccuRate.
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 11 % above the optimum level to a total of 116.0 for the worst orientation;
- The optimum orientation was in range predicted by the SEDA lot-rating tool. There were a number of orientations that provided the worst, or close to the worst energy loads, but the overall range in terms of impact on energy loads was small;
- At the presented orientation, increasing the external shielding from suburban to heavy in AccuRate resulted in an increase of 9 % in the annual total energy load to 125.7 MJ/m²/annum, exceeding the cooling and annual total loads achieved by altering the orientation alone;
- In BERS, increasing the shielding and decreasing the natural ventilation has a negligible impact on the energy loads;
- For this dwelling, increasing the external shielding alone has a greater impact on energy efficiency than altering the orientation;
- In AccuRate, removing the ceiling insulation to pre-BCA 2003 standards results in an increase in the annual total load of some 250 % to 298.2 MJ/m²/annum.

4.5.3 Case study 4 - project home

The majority of plans supplied for this study were variations of this type, which is a typical suburban family dwelling and typical project home.

Figure 4.7 Case study 4



- Large lot (725 m²), 5 star lot rating;
- Single storey brick veneer on slab, tiled roof;
- Large (194 m²), 4 bedroom, 2 pedestal.

The focus of this case study was on exploring the differences that arise from the different zoning regimes. These variations in zoning affect the conditioned floor area for each simulation and were expected to impact significantly on the energy loads.

Table 4.5 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	13.4	188.5	201.8	
BERS	32.0	104.6	132.6	3.0
AccuRate	13.6	141.1	154.7	

The dwelling appears to perform much better in BERS. This arises in part from the zoning regimes. Additionally;

- There was a marked variation in the conditioned floor areas (BERS 51 % and AccuRate 75 %), arising from variations in the program zonings;
- The master bedroom is separated from the other three by the living spaces, limiting the area that could be conditioned in BERS. It is reasonable to assume that the master bedroom would have been conditioned ahead of the other bedrooms;
- Alternately, bedrooms two, three and four could have been conditioned. This would have increased the conditioned floor area in BERS to 125m². It would also have involved redrawing those portions of the floor plan in BERS.
- It is only when comparing the need to make these judgements in BERS with the ease of entering the zones as indicated on the plan in AccuRate, that the limitations and cumulative impact of these judgements become apparent;
- The differences between the zoning in the BERS and AccuRate also mean that rooms of different orientations are being conditioned;
- The limited number of zones available in BERS imposes fewer internal barriers to natural ventilation flow; and

- In addition, the zone types of living and living/kitchen in AccuRate create a greater internal heatload that has to be ventilated out of the dwelling. See Appendix C.2.3 for a detailed explanation of these differences.

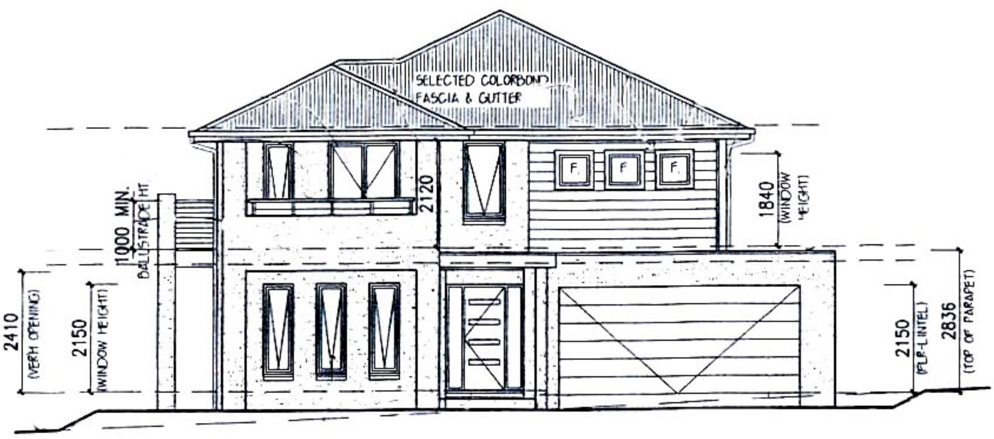
Combining sub-division and dwelling performance, the main findings from this case study were;

- Improved ventilation modelling has resulted in a decrease of 24 % in the annual total load between NatHERS and AccuRate;
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 10.5 % above the optimum level to a total of 159.4 MJ/m²/annum for the worst orientation;
- The optimum orientation was in range predicted by the SEDA lot-rating tool. There were a range of orientations that provided the worst or close to the worst energy loads, but the overall range in terms of impact on energy loads was small;
- At the existing orientation, increasing the external shielding, and reducing natural ventilation, has almost no impact on the energy load in BERS. This is an expected result as this is an acknowledged weakness in this program;
- At the presented orientation, increasing the external shielding in AccuRate from suburban to heavy results in an increase of 8 % in the annual total energy load to a total of 167.5 MJ/m²/annum;
- For this dwelling, increasing the external shielding alone has a greater impact on energy efficiency than altering the orientation - the relationship between lot coverage and degree of external shielding needs to be considered;
- This dwelling is similar in size to case study 1, yet at 154.7 MJ/m²/annum, uses 43 % more energy.

4.5.4 Case study 5 - project home

After case study 4, the majority of plans supplied for this study were variations of this type of dwelling, which is typical of larger suburban family dwellings in new developments.

Figure 4.8 Case study 5



- Large lot (640 m²), 5 star lot rating;
- Two storey, brick veneer on slab, brick veneer and lightweight clad elevated timber floor, metal roof;
- Large (287m²), 4 bedroom, 3 pedestal, with study (or SOHO) on ground floor.

As with the preceding case study, the focus was on examining the differences that arise from the different zoning regimes in BERS and AccuRate.

Table 4.6 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	12.3	160.3	172.6	
BERS	18.1	89.2	107.3	3.5
AccuRate	12.9	107.6	120.5	

As with case study 4, the dwelling seems to perform much better in BERS. Possible explanations include;

- There was some variation in the conditioned floor areas (BERS 56 %, AccuRate 60 %), arising from variations in the program zonings;
- The BERS zoning regime results in only six zones being created over the two levels, compared with eleven internal zones in AccuRate;
- This limited number of zones impacts on the way the program interprets barriers in the internal ventilation patterns;
- The internal zones in AccuRate more closely resemble the internal wall divisions;
- In addition, the zone types of living and living/kitchen in AccuRate create a greater internal heat load that has to be ventilated out of the dwelling.

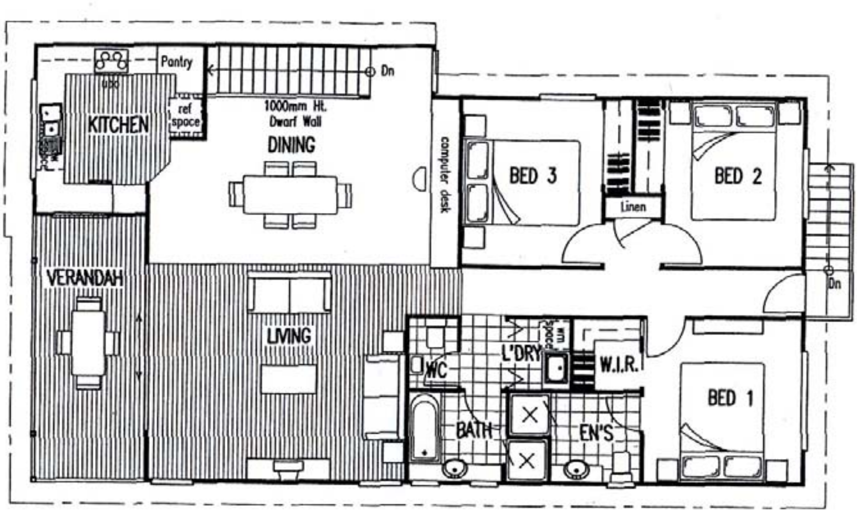
Combining sub-division and dwelling performance, the main findings from this case study were;

- Improved ventilation modelling has resulted in a decrease of 30 % in the annual total load between NatHERS and AccuRate.
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 16 % above the optimum level to a total of 137.6 MJ/m²/annum for the worst orientation;
- The optimum orientation was in a range predicted by the SEDA lot-rating tool. There were two orientations that provided the worst, or close to the worst energy loads;
- At the presented orientation, increasing the external shielding and reducing natural ventilation has almost no impact on the energy load in BERS. This is an expected result as this is an acknowledged weakness in this program;
- At the presented orientation, increasing the external shielding from suburban to heavy in AccuRate results in an increase of 12 % in the annual total energy load to a total of 134.4 MJ/m²/annum;
- The impact of increased external shielding is similar in range and total to that achieved by altering the orientation alone.

4.5.5 Case study 6 - project home

Dwellings such as these were once common; however only two sets of plans were supplied. Elevated lightweight dwellings are now more common in inner urban areas where increasing densities in older areas have created a demand for infill 'replica Queenslanders'[9].

Figure 4.9 Case study 6



- Small lot 400 m², lot orientation is unknown (generic project home plan);
- Elevations were not provided for this dwelling;
- Elevated, lightweight construction with garage, laundry and study (SOHO) at ground level;
- 189m², 3 bedroom, 2 pedestal.

Table 4.7 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	64.9	228.1	293.0	
BERS	72.0	125.6	197.6	1.5
AccuRate	65.9	175.2	241.1	

This is the type of dwelling referred to by the Queensland Masters Builders Association (QMBA) in 5.3 and it would seem that lightweight elevated dwellings are still not being modelled as performing with an acceptable degree of energy efficiency. To place this comment in context however, this is just one example and this particular dwelling has limited potential for cross ventilation in the main living and dining areas. It is also important to remember that thermal tools assume that both heating and cooling will be used to moderate internal temperatures once they reach set temperatures and that this assumption can be misleading where mechanical cooling is not used.

As with case studies 4 and 5, the dwelling appears to perform better in BERS. Possible explanations include;

- There was some variation in the conditioned floor areas (BERS 60 %, AccuRate 66 %), arising from variations in the program zonings;

[9] The term 'Queenslander' refers to the highest timber and tin houses that emerged in the 1870s as a response to both the availability of timber, the topography and the climate.

- In AccuRate, the downstairs bedroom is being treated as a SOHO with a zone type of 'living' indicating a heatload equivalent to equipment such as computers. This zone is conditioned;
- In addition, the zone type of living/kitchen assigned to the kitchen area creates a greater internal heatload that has to be ventilated out of the dwelling;
- The treatment of the under floor area - the bedroom and bathroom areas are located over an open under floor area. As a result, this lightweight dwelling will be more affected by external temperature variations, as indicated by the higher heating and cooling loads;
- It is not know what assumptions BERS makes for such areas;
- In AccuRate, this area is considered as 'open air'. The treatment of under floor areas in lightweight elevated dwellings is examined in further detail in case study 8.

Combining sub-division and dwelling performance, the main findings from this case study were;

- Improved ventilation modelling has resulted in a decrease of 18 % in the annual total load between NatHERS and AccuRate.
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 17 % above the optimum level to a total of 254.6 MJ/m²/annum for the worst orientation;
- The optimum and the worst orientations were outside the range predicted by the SEDA lot rating tool;
- At the existing orientation, increasing the external shielding and reducing natural ventilation has almost no impact on the energy load in BERS. This is an expected result as this is an acknowledged weakness in this program and will not be re-examined in any of the following case studies;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 7 % in the annual total energy load to a total of 259.4 MJ/m²/annum;
- The impact of increased external shielding is similar in total to that achieved by altering the orientation alone.

4.5.6 Case study 7 - project home

This split level dwelling with large expanses of glazing to capture views and breezes is the type of dwelling design that is seeking to respond to the challenges imposed by increasingly steep slopes and restrictions on cut and fill techniques.

Figure 4.10 Case study 7

- Large lot 903 m², 5 star lot rating;
- Three levels on a sloping (18°) site;
- Blockwork on slab lower floor, lightweight external walls on upper levels, metal roof with minimal (5º) pitch;

- Large dwelling (263m²), 3 bedroom, 2 pedestal.
- It is assumed that the garage floor is a concrete slab and that the upper level floors are timber;
- The difference between this dwelling and case study 6 is that the floors are located in close proximity to the slope and the under-floor area is set to 'ground'.

Table 4.8 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	44.5	267.3	311.8	
BERS	113.1	301.6	414.7	0.5
AccuRate	47.8	137.0	184.8	

- There are variations in the total floor area and conditioned floor areas (BERS 56 % and AccuRate 46 %) arising, as before, from the differing data entry methods in the two programs;
- The ensuite adjacent to the main bedroom and the access passageways adjacent to the upper level bedrooms are not conditioned in AccuRate. This level of selection is not possible in BERS;
- There may be problems with the AccuRate calculations as the simulation ran with an error report 'problem with vertical alignment of zones'.
- Another possible explanation is that the impact of the limited data that can be entered in BERS becomes more apparent in larger and more complex dwellings.

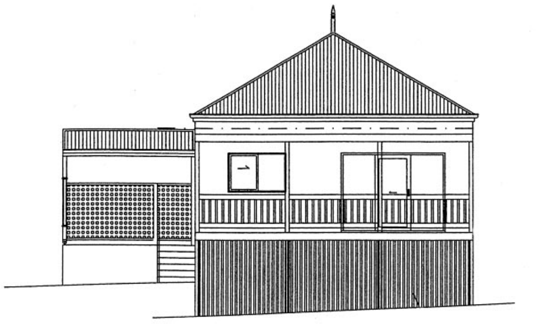
Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling has resulted in a decrease of 41 % in the annual total load between NatHERS and AccuRate.
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 23 % above the optimum level to a total of 239.2 MJ/m²/annum for the worst orientation;
- The optimum and worst orientations are in the range predicted by the SEDA lot rating tool;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 15 % in the annual total energy load to a total of 212.9 MJ/m²/annum;
- The impact altering the orientation alone is more significant than that of altering the external shielding;
- For these complex dwellings, designers require a tool that will enable them to test the energy efficiency of a variety of insulating and shading devices at the design development stage, rather than reacting to an inappropriate rating at a later stage.

4.5.7 Case study 8 - prefabricated dwelling

This form of dwelling has developed from prefabricated classroom construction methods.

Figure 4.11 Case study 8



- Small lot (261 m²), 3 star lot rating;
- Single storey, elevated, lightweight construction, metal roof;
- Small dwelling (100 m²), 3 bedroom, I pedestal.

The total conditioned floor areas and the rooms comprising that total are similar for both programs, enabling direct comparisons between the programs.

This case study highlights the anomalies created by the treatment of the under floor area. The above dwelling elevations show the under floor area to be enclosed with battens and there are problems with modelling such spaces in the thermal programs. In BERS, the dwelling was initially modelled as a single storey, high set dwelling with an open under floor area. It is not known what assumptions BERS makes for such areas. In AccuRate, the dwelling was initially modelled with a sub-floor zone, set as 'open'. The results of these simulations follow;

Table 4.9 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	60.7	125.5	186.3	
BERS Under floor open	131.8	78.9	210.7	1.5
AccuRate Open sub-floor Moderate shielding	61.9	98.4	160.3	
AccuRate Open sub-floor Heavy shielding	61.7	109.1	170.8	

The above table shows the expected drop in cooling between NatHERS and AccuRate, with the cooling and total energy loads increasing as the external shielding increases.

The BERS heating and cooling loads have not been transposed and it is the variation in cooling loads between the programs that is the issue.

In AccuRate, the sub-floor zone was removed and the zone below the dwelling set to outdoor air. The results of these simulations follow:

Table 4.10 Thermal program comparisons with open air under floor in AccuRate

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	157.6	280.5	309.1	
BERS Under floor open	131.8	78.9	210.7	1.5
AccuRate No sub floor zone Open air below	158.6	119.3	278.0	

The heating, cooling and annual total loads in BERS now appear in context and the treatment of the underfloor area has been identified as one cause of the variation in the energy loads between the programs.

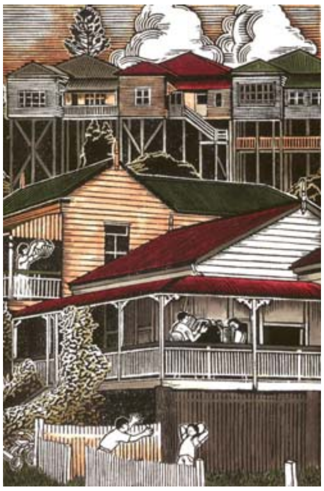
One final variation was trialed to highlight the significance of this issue in both programs. The under floor area was changed from open to enclosed in BERS, which is another possible interpretation of the impact of closely spaced battens. The results of all these simulations appear in the following table:

Table 4.11 Thermal program comparisons with varying under floor settings

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	157.6	280.5	309.1	
BERS Under floor open	131.8	78.9	210.7	1.5
BERS Under floor enclosed	86.8	67.4	154.2	2.5
AccuRate Sub-floor open Moderate shielding	60.7	98.4	160.3	
AccuRate No sub floor zone Open air below	158.6	119.3	278.0	

The performance of these spaces would seem to be somewhere between the extremes of an enclosed sub-floor zone that has minimal openings for ventilation, and the completely open under floor indicated by 'open air'. While these areas are subject to air transfers and are open to the effect of both hot and cold air, anecdotal evidence suggests that, for the most part these areas are shaded and cooler than the outside air in summer.

Figure 4.12 Variations in sub-floor areas



Source: (Fisher and B Crozier (eds), 1994)

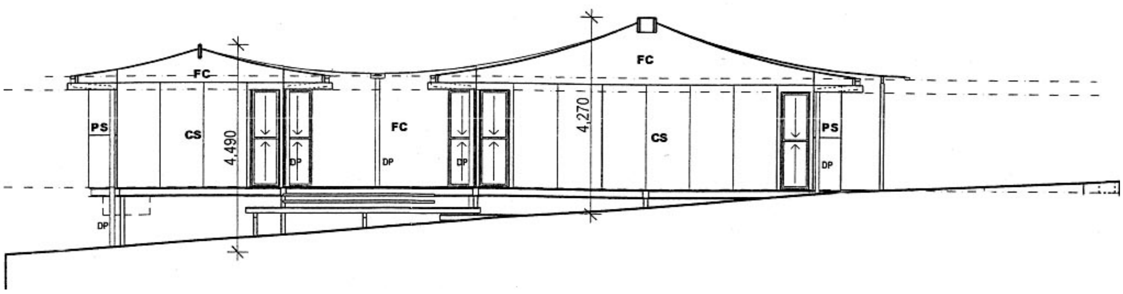
A better understanding is needed of the ventilation effects of these battened sub-floor areas and further enhancement of the programs may be needed to model such spaces better.

Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling has resulted in a decrease of 14 % in the annual total load between NatHERS and AccuRate.
- Using the open sub-floor setting in AccuRate, altering the orientation resulted in an increase in the annual total load of 20 % above the optimum level to a total of 164.1 MJ/m²/annum for the worst orientation;
- The optimum orientation was outside the range predicted by the SEDA lot-rating tool. There were a range of orientations that provided the worst, or close to the worst energy loads, and the overall range in terms of impact on energy loads is significant;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 6 % in the annual total energy load to a total of 170 MJ/m²/annum;
- The impact of increased external shielding is similar in total to that achieved by altering the orientation alone.

4.5.8 Case study 9 - prefabricated dwelling

Figure 4.13 Case study 9



- Small lot (402 m²), 5 star lot rating;
- Single storey, elevated, lightweight construction, metal roof;
- Small (140m²), 2 bedroom, 1 pedestal.

The conditioned floor areas are similar, but, as in other case studies, the rooms comprising that total vary. In BERS, the two living zones mean that only one bedroom can be conditioned. In AccuRate, both bedrooms are conditioned, as is one of the living areas.

Table 4.12 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	56.0	213.4	268.8	
BERS Terrain suburban	75.3	185.5	260.8	1.5
AccuRate Moderate shielding	56.9	113.1	169.9	
AccuRate Heavy shielding	56.8	132.6	189.4	

The above table shows the expected drop in cooling between NatHERS, BERS and AccuRate, with the cooling and total energy loads increasing in AccuRate as the external shielding increases.

- Both programs were affected by the large area bias;
- In AccuRate, the energy loads can be expected to reduce further when the area adjustment algorithm is reapplied.

Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling has resulted in a decrease of 37 % in the annual total load between NatHERS and AccuRate.
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 17 % above the optimum level to a total of 197.5 MJ/m²/annum for the worst orientation;
- The optimum orientation was in range predicted by the SEDA lot-rating tool. The worst orientation was outside the range predicted;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 12 % to a total of 189.4 MJ/m²/annum;
- For this dwelling, the impact of altering the orientation is similar in range and total to the impact of increasing the external shielding.

4.5.9 Summary of findings for detached dwellings

One of the objectives of examining the detached dwellings was to determine if a correlation existed between lot rating and dwelling ratings. This objective will not apply to the examination of the attached dwellings, which will focus on orientation and shielding alone. As a result, the findings for the detached and attached dwellings have been summarised separately.

As explained earlier in this report, a significant variation in annual total load could be considered as a variation that causes the star rating to alter by ±½ Star. The absence of the adjusted star ratings makes it difficult to determine what constitutes a significant variation in energy efficiency and has added an unexpected degree of difficulty in interpreting the data. In turn, this has led to the need to include more detail in each case study in place of a 1-5 star indicator. The point of comparison then must lie within the simulations run for each dwelling and in the totals between the case studies.

Assessing energy efficiency

One of the drivers to improve the Nationwide House Energy Rating Scheme (NatHers) was the need to improve ventilation modelling in tropical and sub-tropical climates and provide designers with a tool to augment passive design principles and improve the thermal performance of residential dwellings (Commonwealth of Australia, 2004). As explained earlier in this report, the NatHERS ventilation model makes some provision for ventilation, but is far less detailed than AccuRate's ventilation model. NatHERS provided a benchmark for comparison with BERS and AccuRate and the results of these simulations follow:

Table 4.13 NatHERS and AccuRate - impact of improved ventilation modelling on energy efficiencies

Case study dwelling	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Decrease in annual total load
1	19.1 – 21.0	150.2 – 86.6	169.1 – 107.7	37 %
2	43.9 – 43.9	152.9 – 89.1	196.4 – 133.0	32 %
3	17.0 – 17.3	125.1 – 97.4	142.1 – 114.8	20 %
4	13.4 – 13.6	188.5 – 141.1	201.8 – 154.7	24 %
5	12.3 – 12.9	160.3 – 107.6	172.6 – 120.5	30 %
6	64.9 – 65.9	228.1 – 175.2	293.0 – 241.1	18 %
7	44.5 – 47.8	267.3 – 137.0	311.8 – 184.8	41 %
8	60.7 – 61.9	125.5 – 109.1	186.3 – 160.3	14 %
9	56.0 – 56.9	213.4 – 113.1	268.8 – 169.9	37 %

The project found that the improved ventilation modelling resulted in a decrease of between 14 and 41 % in the annual total load between NatHERS and AccuRate. What is important is the marked variation in the range of annual total loads (241 1 to 107.7) between the most (case study 1) and least efficient (case study 6) of the case study detached dwellings. This variation suggests further design changes are required to optimise energy efficiency in new dwellings. The impact of the variation is yet to be quantified in terms of star ratings; but it is timely to recall that the 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.

Benchmarking energy efficiency

The key informants in Phase One identified the need for benchmark dwellings so that developers can achieve a sustainable outcome without losing any competitive edge in the market. The key informants felt that at present, other than the BCA DTS Provisions, there is no clear measure of how to achieve the necessary standard, or to meet increasing standards.

This project has identified the individual dwellings, Research House and the Greensmart Home (case studies 1 and 2), as being energy efficient benchmarking dwellings. These dwellings were selected for examination because they address the range of sub-divisional issues developers 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. The following discussion addresses lot topography, orientation, size and density by comparing the energy efficient performance of the case study dwellings with the benchmark dwellings to inform the development of future tools for sub-divisional layouts.

Topography

The detached dwelling types fall into two broad categories, those designed for traditional ‘cut and fill’ lots and those designed for sloping lots. Research House (case study 1) has set the benchmark for the more traditional Greenfield ‘cut and fill’ slab dwellings and the Greensmart Home (case study 2) has set the benchmark for the sloping site dwellings. As discussed in the detailed case study examination at Appendix C, 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 2 included additional ventilation features that are not included in the modelling.

Table 4.14 Comparison of the energy loads for dwellings designed for flat or cut and fill lots

Case study	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum
Case study 1 – individual Large flyash veneer on slab	21.0	86.6	107.7
Case study 3 – project Small brick veneer on slab	17.3	97.4	114.8
Case study 4 – project Large brick veneer on slab	13.6	141.1	154.7
Case study 5 – project Large, double storey, brick veneer and lightweight on slab	12.9	107.6	120.5

It should be noted that these dwellings represent the latest generation of slab dwellings and include the relatively recently introduced DTS levels of external wall and ceiling insulation. The results in Table 4.14 do not reflect the energy consumption of dwellings in pre-BCA 2003 developments.

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. As a result, this discussion focuses on the performance of the range of dwellings that appear to have been designed for sloping sites.

Table 4.15 Comparison of the energy loads for dwellings designed for sloping sites

Case study	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum
Case study 2 – individual Small lightweight elevated	43.9	89.1	133.0
Case study 6 – project Small lightweight elevated	65.9	175.2	241.1
Case study 7 – project Large, split level lightweight	47.8	137.0	184.8
Case study 8 – prefabricated Small elevated lightweight	60.7	98.4	160.3
Case study 9 – prefabricated Small elevated lightweight prefabricated	56.9	113.1	169.9

The Greensmart Home (case study 2) has set the benchmark for the lightweight dwellings. However, this dwelling has above required levels of insulation and has different flooring to the other dwellings. Case studies 6 and 8 also have above required levels of insulation, while case study 6 represents the typical example of these types of dwelling. By comparison, case study 7 is the split level dwelling with large expenses of glazing to capture views and breezes and is the type of dwelling design that is seeking to respond to the challenges imposed by increasingly steep slopes and restrictions on cut and fill techniques.

The range of cooling and annual total loads shown above highlights the need for dwelling designers to have access to a tool that will allow them to augment passive design principles and test the energy efficiency of designs targeted for complex sites. This would enable them to test a variety of orientation, insulation and shading devices throughout the design development stage, rather than reacting to an inappropriate rating at a later stage.

Orientation

This project quantifies the link between lot and dwelling orientation. The impact of altering the orientation of the case study dwellings at 45° increments throughout 360° increased the annual total load (and decreased energy efficiency) by between 10 and 23 % above the optimum level for each dwelling.

Table 4.16 Impact of orientation on energy efficiencies

Case study dwelling	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Increase in annual total load
1	17.0 – 20.8	80.8 – 87.1	97.4 – 107.9	10 %
2	34.6 – 43.2	96.0 – 110.8	130.7 – 154.1	18 %
3	15.8 – 17.8	89.1 – 98.2	104.9 – 116.0	11 %
4	10.3 – 13.7	133.8 – 145.7	144.1 – 159.4	10.5 %
5	12.0 – 15.5	106.4 – 122.2	118.4 – 137.6	16 %
6	67.2 – 72.0	152.3 – 182.5	216.7 – 254.6	17 %
7	59.7 – 65.5	134.5 – 173.8	194.2 – 239.2	23 %
8	48.4 – 58.2	87.6 – 105.9	136.1 – 164.1	20 %
9	57.4 – 49.4	111.7 – 148.1	169.1 – 197.5	17 %

Again, the variation in annual total loads is important as the range is from 107.9 MJ/m²/annum (case study 1) to 254.6 MJ/m²/annum (case study 6).

The correlation between optimum energy efficiency and lot orientation is not as clear-cut as first thought. In six of the nine studies, the optimum orientation complied with the SEDA tool guidelines and the same applied to the worst orientations. The problem is that in three out of the nine case studies, or a third, the highest energy loads did not occur when the dwelling is oriented at a 1 Star Lot under the SEDA tool. This study starts to integrate lot and dwelling packages and quantify the link in terms of energy efficiency.

Lot size
Five of the nine case study dwellings were small, responding to the changing demographic of Australian households and to the increasing diversity in lot sizes in Greenfield developments.

Table 4.17 Comparison of the energy loads for dwellings designed for small lots

Case study	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum
Case study 2 - individual Small lightweight elevated	43.9	89.1	133.0
Case study 3 – project Small brick veneer on slab	17.3	97.4	114.8
Case study 6 – project Small lightweight elevated.	65.9	175.2	241.1
Case study 8 – prefabricated Small elevated lightweight prefabricated	60.7	98.4	160.3
Case study 9 – prefabricated Small elevated lightweight prefabricated	56.9	113.1	169.9

All of these dwellings will be affected by the large area bias that is still present in the programs at this stage. The performance of these dwellings, in terms of their eventual star ratings, could be expected to improve when the area adjustment logarithm is re-applied.

While a detailed examination of the dwelling designs is outside the scope of this report, some points still emerge. In this grouping, case study 3, the small brick veneer, appears to outperform the elevated dwellings. It is small with only 104 M² internal floor area and has a high percentage of windows (21 %). The floor area compares to case study 8, which has only 13 % window area. case study 6 (189 m²) is larger than case study 2 (150 m²), yet at 11 % window area, has half the window space of the smaller dwelling.

As discussed in case study 8, there is a question outstanding regarding the treatment of the sub-floor zones in these elevated dwellings and this will be affecting the performance of the elevated dwellings.

Density
This portion of the study was triggered within the project and is outside the original scope of the project. The high percentage of small lots, coupled with the Phase One key informants identifying increasing densities in Greenfield developments as an issue, triggered an examination of the impact of increased densities in this study. Examining one of the individual dwellings that was known to be located in close proximity to its neighbour lead to an examination of the impact of increasing the external shielding for all the case study dwellings. While BERS has a range of external barriers, the impact on the energy efficiency is negligible and so this examination was only possible in AccuRate, which enables external ventilation to be considered and then its effects to be progressively reduced through increased external barriers.

Table 4.18 Impact of increased external shielding on energy efficiencies

Case study	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Increase in annual total load
1	21.0 – 20.9	86.6 – 92.1	107.7 – 113.0	5 %
2	43.9 – 43.9	89.1 – 104.8	133.0 – 148.7	11 %
3	17.3 – 17.3	97.4 – 108.5	114.8 – 125.7	9 %
4	13.6 – 13.2	141.1 – 154.3	154.7 – 167.5	8 %
5	12.9 – 12.8	107.6 – 121.6	120.5 – 134.4	12 %
6	65.9 – 65.6	175.2 – 193.8	241.1 – 259.4	7 %
7	47.8 – 47.4	137.0 – 165.5	184.4 – 212.9	15 %
8	61.9 – 61.7	98.4 – 109.1	160.3 – 170.8	6 %
9	56.0 – 56.8	113.1 – 132.6	169.9 – 189.4	12 %

The main finding from this study is the impact on the energy loads that result from increased external densities, which reduce natural ventilation. It quantifies and confirms the 'common knowledge' principles of orienting for ventilation.

The variation in annual total loads is of importance, ranging from 113.0 MJ/m²/annum (case study 1) to 259.4 MJ/m²/annum (case study 6). Comparing this range to that achieved by altering the orientation, (107.9 MJ/m²/annum for case study 1 to 254.6 MJ/m²/annum for case study 6), reveals that the impact of increasing the external shielding was either similar to, or exceed the impact of altering the orientation alone.

Because of the number of simulations involved, the combined effect of poor orientation and heavy external shielding was not explored in detail. However in case study 3, which is one of the better performing dwellings, the worst case combination of poor orientation and increased external shielding resulted in an increase of 40 MJ/m²/annum, or approximately 30 %, above the optimum annual total load.

A number of points concerning dwelling assessment 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 as rating assessment is 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 in both programs;
- Practice notes relating to small lots and shielding are problematic, as slope angle and direction can influence access to breezes;
- Given the increase in energy indicated in the heavier shielding, there may be commercial pressures on an assessor to select the optimum external conditions for the dwelling;
- 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 the assessors' objective is to increase the star rating;
- Whatever the basis for the shielding assumption, it is not disclosed in the ratings statement in either program at present;
- These issues are a function of the use of the programs and not of the programs' performance.

It is likely that in some instances a project home will be sited to suit a sub-divisional layout that is inappropriate for the dwellings design. Clearly, the dwellings with the greatest range of annual total loads are the most susceptible to poor orientation. 'Blank canvas' EER's (suburban setting, no significant external barriers) displaying approximate star ratings throughout 360° of rotation could easily be displayed on the plans as an added feature for the energy consumption conscious consumer.

It is also likely that increasing urban densities (structures or vegetation) will eventually reduce or block the prevailing breezes. The impact of this growth and change is captured in the ACT example where dwellings are re-assessed at point of sale. While the intent behind that legislation was to extend the impact of energy efficiency into the existing dwelling market, use of the latest generation of thermal tools will enable the process to capture, and examine, the impact of ongoing change.

4.6 Attached Dwellings

For the purpose of this project, medium density is defined as two to three storey developments, while high density is defined as being four stories and over. These are common usage terms and may not correspond with definitions used by local authorities. The aim of this section is to examine the adequacy of current design options in the context of an emerging energy code for medium and high-density dwellings. The BCA is to include energy efficiency provisions for such dwellings from 2005. Provisions already exist in Victoria.

According to the AGO, in 1998 attached dwellings accounted for 23 % of the total housing stock and this was predicted to increase to 26 % by 2010. DLGP notes that demographic changes, including an increase in single-person households, are contributing to the increased demand for multi-unit dwellings (DLGP, 2004). .

The methodology for this portion of the study was to examine a range of one, two and three bedroom medium and high-density dwellings and compare the heating, cooling and annual total loads achieved in NatHERS with those achieved in AccuRate.

Assessing the impact of orientation on energy efficiency

To assess the impact of orientation on energy efficiency, the attached dwellings were modelled throughout 360° at 45° increments.

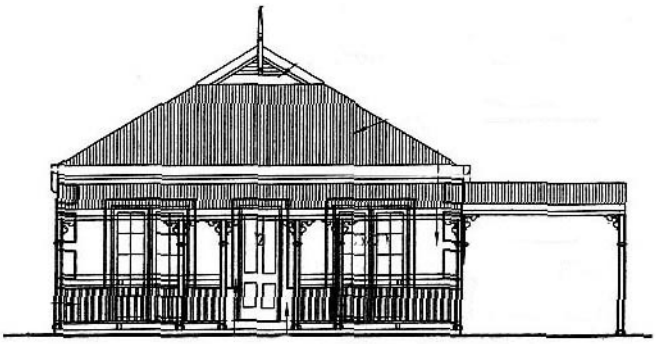
Assessing the impact of increased shielding on energy efficiency

To assess the impact of increased external shielding on energy efficiency, the external shielding for the medium density dwellings was increased in AccuRate from moderate (suburban) to heavy (inner urban). High-density dwellings are more likely in inner urban areas and so heavy shielding was assumed.

Comparative energy efficiencies of attached and detached dwellings

To compare the relative energy efficiencies of the medium and high-density case study dwellings, the annual total loads were compared with those achieved for case study 3 (Figure 4.14), a small brick veneer on slab detached dwelling.

Figure 4.14 Comparative detached case study 3



This dwelling was selected as it has similar constructions and internal floor space. The AGO has provided the benchmark for this comparison;

Modelling showed that attached dwellings were 36 % more efficient on a per square metre basis in comparison with separate dwellings (AGO, 1999).

As explained earlier in this report, the case study dwellings have been modelled in locations that represent the majority of housing development in SEQ. The detached dwellings were modelled as if located in an outer urban Greenfield development and the attached dwellings were modelled as if located in an inner urban Brownfield development. Urban sprawl means that there are increasing distances between these outer and inner urban 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 comparative detached dwelling 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.

4.6.1 Case study 10 - medium density dwelling

The apartment selected for analysis was a mid level apartment located in the centre of a complex of twenty, one bedroom apartments.

Figure 4.15 Medium density case study 10

- Small (57m²), one bedroom apartment.

The apartments at this level have conditioned apartments above and below, but not directly alongside as each apartment opens to a covered stairwell area. The floor area is similar to high-density case studies 14 and 15.

Figure 4.16 Case study 10 floor plan

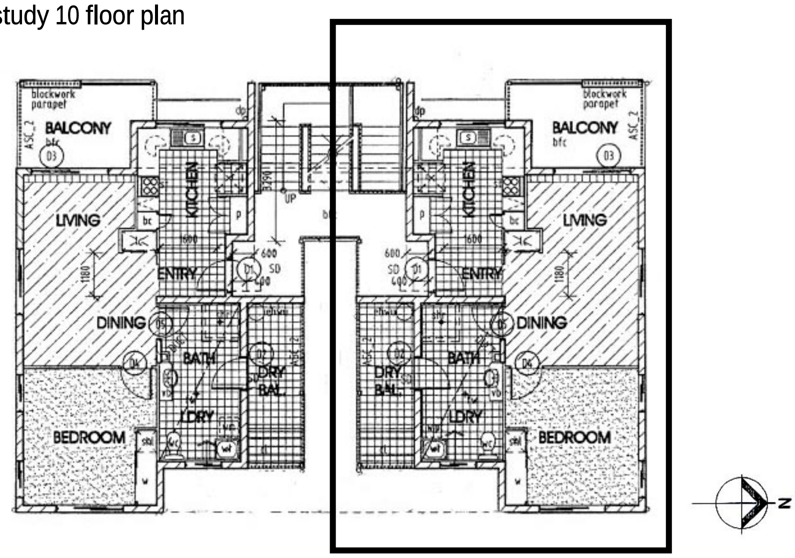


Table 4.19 Thermal program and shielding comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	36.5	88.1	124.6	
AccuRate Moderate shielding	36.9	53.7	90.6	
Heavy shielding	36.9	62.2	99.1	
Attached dwelling comparison Case study 3 Heavy shielding	17.3	108.5	125.7	

The above simulation shows the expected drop in the cooling and annual total loads between NatHERS and AccuRate at a moderate (suburban) setting. The cooling and annual total loads then increase as the external shielding reflects the apartments expected inner urban setting. For this reason, heavy shielding was selected as the default for the medium density orientation simulations.

Examining the orientation and external shielding, the main findings from this case study were:

- In AccuRate, altering the orientation resulted in an increase in the annual total load of 9 % above the optimum level to a total of 103.6 MJ/m²/annum for the worst orientation;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 9 % to a total of 99.1 MJ/m²/annum;
- For this dwelling, the impact of altering the orientation is similar in range and total to the impact of increasing the external shielding;
- When both are modelled with the same degree (heavy) of external shielding, this apartment was 21 % more efficient than detached dwelling, case study 3.

Figure 4.17 Medium density case studies 11 to 13

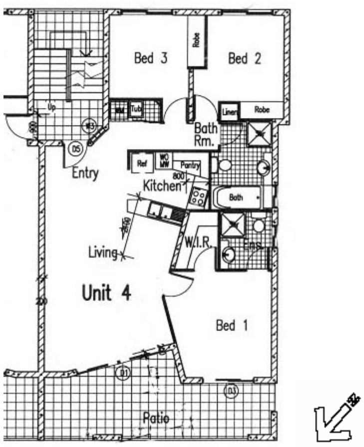
- Three mid-level apartments were selected. Two end apartments differ in layout and footprint and one is partially located over the garage area. The third apartment is has the same layout as one of the end apartments, but is located within the complex.
- 100-110 m² internal space with three bedrooms, 2 pedestals.

These apartments are similar in both conditioned and total floor area to case study 3, the small brick veneer on slab dwelling and so will be used to test the AGO finding that attached dwellings are 36 % more efficient than detached dwellings.

4.6.2 Case study 11 - medium density dwelling

The following case studies share the same internal layout, but differ in the degree of exposure to external conditions.

Figure 4.18 Case study 11 floor plan



Case study 11 is an end apartment with three external walls and has conditioned spaces (neighbouring apartments) on one side, above and below.

Table 4.20 Thermal program and shielding comparisons

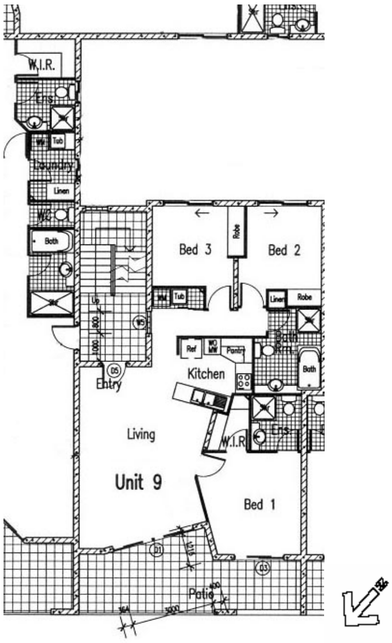
Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	16.5	54.6	71.1	
AccuRate Moderate shielding	16.5	43.8	60.4	
AccuRate Heavy shielding	16.5	51.5	67.6	
Attached dwelling Case study 3 comparison Heavy shielding	17.3	108.5	125.7	

Examining the orientation and external shielding, the main findings from this case study were:

- In AccuRate, altering the orientation resulted in an increase in the annual total load of 27 % above the optimum level to a total of 76.2 MJ/m²/annum for the worst orientation;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 11 % to a total of 67.6 MJ/m²/annum;
- These findings need to be viewed in context, as while the increases appear to be large, the overall totals are comparatively small when compared to the detached dwelling energy consumptions.
- When both are modelled with the same degree (heavy) of external shielding, this apartment is 46 % more efficient than detached dwelling, case study 3.

4.6.3 Case study 12 - medium density dwelling

Figure 4.19 Case study floor plan



Case study 12 is a central unit with two external walls with conditioned spaces on two sides and above. It is partially located over another apartment and the rear bedrooms are located over an entry courtyard. These changes affect the annual total load as shown in the following table:

Table 4.21 Thermal program and shielding comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	18.4	47.2	65.6	
AccuRate Moderate shielding	18.4	37.0	55.4	
AccuRate Heavy shielding	18.4	42.3	60.8	
Attached dwelling Case study 3 comparison Heavy shielding	17.3	108.5	125.7	

As expected, there are variations in the heating, cooling and annual total loads between the case studies arising from the differences in neighbouring conditioned spaces. However, these differences are minor.

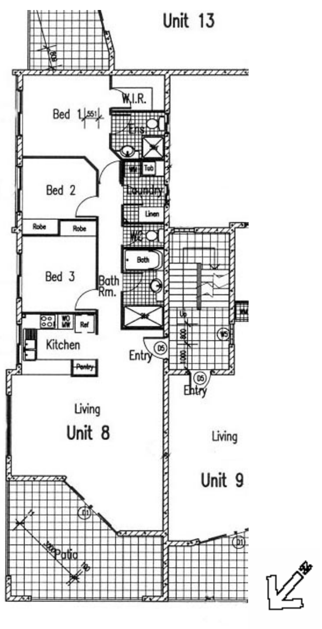
Examining the orientation and external shielding, the main findings from this case study were:

- In AccuRate, altering the orientation resulted in an increase in the annual total load of 17 % above the optimum level to a total of 67.1 MJ/m²/annum for the worst orientation;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 9 % to a total 60.8 MJ/m²/annum;
- For these medium density apartments, the impact of altering the orientation is similar in range and total to the impact of increasing the external shielding:
- These findings need to be viewed in context, as while the increases appear to be large, the overall totals are comparatively small when compared to the detached dwelling energy consumptions;
- When both are modelled with the same degree (heavy) of external shielding, this apartment is 50 % more efficient than the detached dwelling, case study 3.

4.6.4 Case study 13 - medium density dwelling

Case study 13 has three external walls and two common walls with an apartment above it and another below the living area. The majority of this apartment is located over the garage area, which is not a conditioned space.

Figure 4.20 Case study 13 floor plan



There are two areas of interest for this case study. The first is the impact of the footprint, which is rectangular in comparison with case study 12, and has the potential of exposing the long axis to considerable heat gain at some orientations. The second is the absence of a conditioned space below the majority of this apartment. For the purpose of this study, the garage areas have been zoned as open air. There is a sub-floor zone is AccuRate, but this zone does not appear to allow for the degree of openness associated with partially enclosed garage areas.

Table 4.22 Thermal program and shielding comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	40.3	72.9	113.2	
AccuRate Moderate shielding	40.3	67.3	107.9	
AccuRate Heavy shielding	40.3	76.1	116.4	
Attached dwelling Case study 3 comparison Heavy shielding	17.3	108.5	125.7	

The impact of these variations between case studies 12 and 13 is that in case study 13, the heating load has more than doubled and the cooling load increased by approximately 80 % compared to case study 12. In this instance, the impact of heavy shielding negates natural ventilation. Case study 13 is only 7 % more efficient than case study 3.

Examining the orientation and external shielding, the main findings from this case study were:

- In AccuRate, altering the orientation resulted in an increase in the annual total load of 32 % above the optimum level to a total of 143 MJ/m²/annum for the worst orientation;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 8 % to a total of 116 MJ/m²/annum;
- When both are modelled with the same degree (heavy) of external shielding, this apartment is only 7 % more efficient than detached dwelling, case study 3;
- The impact of altering the orientation has a greater impact than increasing the external shielding;
- At the worst orientations, the annual total for this apartment exceeds the levels achieved for case study 3.

The finding that at some orientations this apartment can approach or exceed the energy efficiency of a detached dwelling warrants further discussion.

The zoning regime adopted for each dwelling is a judgment made by the accredited assessor. Case study 1 examined the impact of altering the conditioned floor area as a means of reducing the annual total energy. It would be illustrative to examine the potential for manipulating energy loads for apartments through altering the adjoining zone from outdoor air to neighbour.

Table 4.23 Impact of altering the zone type of an adjoining space on energy efficiencies

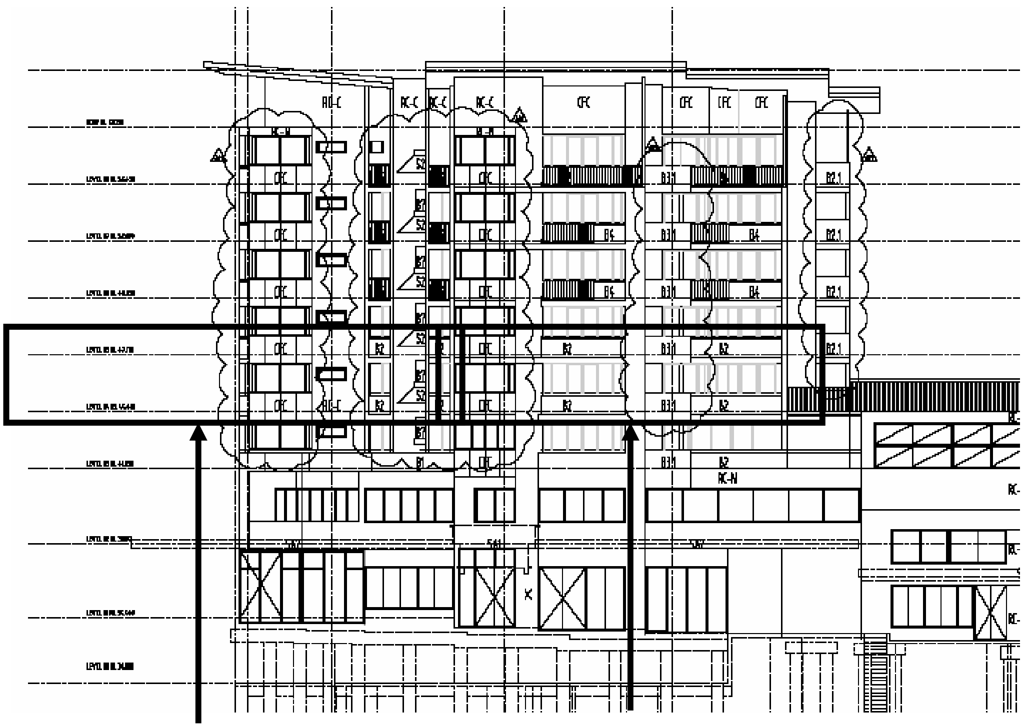
Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	29.4	68.1	97.6	
AccuRate Moderate shielding	29.4	59.5	88.9	
AccuRate Heavy shielding	29.4	70.7	100.1	
Attached dwelling Case study 3 comparison Heavy shielding	17.3	108.5	125.7	

Altering the zone type below the apartment from open air to neighbour has resulted in a reduction of 19 MJ/m²/annum, or 16 % in the annual total loads. The apartment now appears to be 20 % more efficient than a similar sized detached dwelling, as opposed to the earlier 7 % finding. The orientation simulations were not repeated because of the number of simulations involved. The point of this discussion is that either assumption regarding the adjoining zones could be argued as being reasonable. However, neither the neighbouring zonings, nor the external shielding assumptions, are disclosed on the ratings report at this stage.

4.6.5 Case study 14 - high density dwelling

Figure 4.21 High-density case studies 14 to 16

Heavy external shielding was assumed for the high-density dwellings in response to their inner urban location.



- Three mid-level apartments were selected;
- Two one bedroom apartments, 48 – 55m² internal space;
- One two bedroom apartment, 77m² internal space;
- All have conditioned spaces (other apartments) alongside, above and below.

Figure 4.22 Case study 14 floor plan

This apartment is similar in floor area to case study 10, the one bedroom medium density apartment.

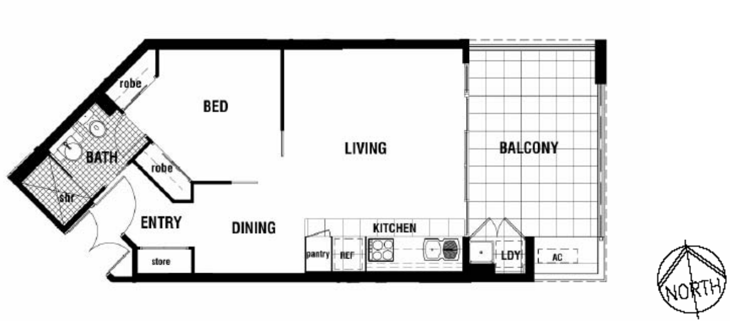


Table 4.24 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	6.8	72.9	79.8	
AccuRate Heavy shielding	6.8	78.0	84.9	
Attached dwelling Case study 3 comparison Heavy shielding	17.3	108.5	125.7	

Examining the orientation and external shielding, the main findings from this case study were:

- In AccuRate, altering the orientation resulted in an increase in the annual total load of 24 % above the optimum level to a total of 91.3 MJ/m²/annum for the worst orientation;
- The overall total energy loads are small when compared to the detached dwellings;
- When both are modelled with the same degree (heavy) of external shielding, this apartment is 33 % more efficient than the detached dwelling, case study 3.

It is also more efficient than a similar sized apartment that lacks the thermal protection afforded by the presence of conditioned spaces adjacent to three of the external walls. This apartment is similar in size to case study 10, but is 16 % more efficient when modelled with the same degree of external shielding.

4.6.6 Case study 15 - high density dwelling

Figure 4.23 Case study 15 floor plan

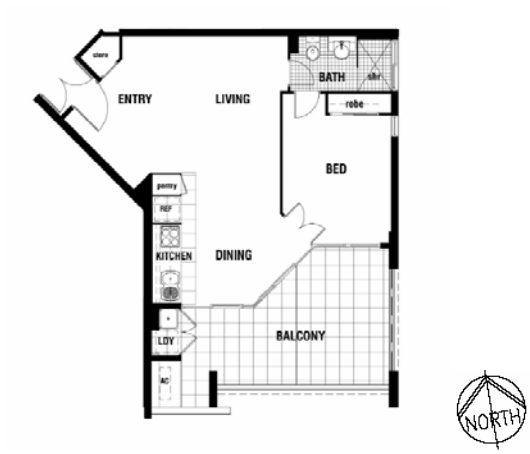


Table 4.25 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	19.1	72.8	91.8	
AccuRate Heavy shielding	19.1	64.3	83.4	
Attached dwelling Case study 3 comparison Heavy shielding	17.3	108.5	125.7	

Examining the orientation and external shielding, the main findings from this case study were:

- In AccuRate, altering the orientation resulted in an increase in the annual total load of 17 % above the optimum level to a total of 91.3 MJ/m²/annum for the worst orientation;
- The overall total energy loads are small when compared to the detached dwellings;
- When both are modelled with the same degree (heavy) of external shielding, this apartment is 33 % more efficient than the detached dwelling, case study 3.

4.6.7 Case study 16 - high density dwelling

Figure 4.24 Case study 16 floor plan

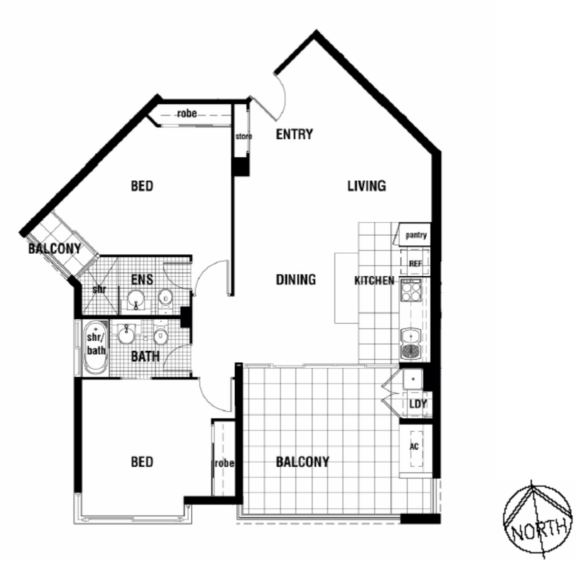


Table 4.26 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	21.2	55.5	76.7	
AccuRate Heavy shielding	21.2	56.5	77.7	
Attached dwelling Case study 3 comparison Heavy shielding	17.3	108.5	125.7	

Examining the orientation and external shielding, the main findings from this case study were:

- In AccuRate, altering the orientation resulted in an increase in the annual total load of 18 % above the optimum level to a total of 84.9 MJ/m²/annum for the worst orientation;
- The overall total energy loads are small when compared to the detached dwellings;

- When both are modelled with the same degree (heavy) of external shielding, this apartment is 38 % more efficient than detached dwelling, case study 3.

4.6.8 Summary of findings for attached dwellings

As explained earlier in this report, the absence of the area adjusted star ratings makes it difficult to determine what constitutes a significant variation and has added an unexpected degree of difficulty in interpreting the data. In turn, this has led to the need to include more detail in each case study in place of a 1-5 star indicator. The point of comparison then must lie within the simulations run for each dwelling and in the totals between the case studies.

Impact of increased external shielding on energy efficiency

The main finding for the detached dwellings was that increasing the external shielding from suburban to heavy resulted in a decrease in energy efficiency that either equalled or exceeded the impact of altering the orientation alone. For the attached dwelling, the shielding for the high-density dwellings was assumed to have heavy external shielding, but the medium density dwellings were modelled with both suburban and heavy shielding and the results follow; be heavy.

Table 4.27 Impact of increased external shielding on energy efficiency

Case study dwelling	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Increase in annual total load
10	36.9 – 36.9	53.7 – 62.2	90.6 – 99.1	9 %
11	16.5 – 16.5	43.8 – 51.5	60.4 – 67.6	11 %
12	18.4 – 18.4	37.0 – 42.3	55.4 – 60.8	9 %
13	40.3 – 40.3	67.3 – 76.1	107.9 – 116.4	8 %

When the shielding for the medium density dwellings was increased from moderate (suburban) to heavy (inner urban), the annual total load increased by between 8 and 11 %. In general, these levels are low compared to those achieved for the detached dwellings (113.0 to 259.4 MJ/m²/annum).

Impact of orientation on energy efficiency

One of the objectives of examining the attached dwellings was to determine if a correlation existed between orientation and energy efficiency. The simulations were all run with heavy external shielding, reflecting the case studies location in an inner urban zone.

Table 4.28 Impact of orientation on energy efficiency

Case study dwelling	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Increase in annual total load
10	39.5 – 46.0	53.6 – 57.7	93.0 – 103.6	9 %
11	12.7 – 17.6	46.9 – 55.8	59.6 – 73.4	27 %
12	18.0 – 18.0	36.1 – 49.0	54.0 – 67.1	17 %
13	39.6 – 59.4	68.8 – 83.5	108.3 – 143.0	32 %
14	1.6 – 6.0	71.9 – 85.2	73.6 – 91.3	24 %
15	5.7 – 16.3	53.9 – 63.7	59.0 – 80.2	35 %
16	12.8 – 15.5	56.2 – 69.3	69.1 – 84.9	18 %

This project has found that orientation plays a significant role in energy efficiency of attached dwellings with the annual total loads varying by between 9 and 32 %. In general, these increases were recorded against optimum performance totals that were low (54.0 to 108.3 MJ/m²/annum) when compared to the detached dwellings (97.4 to 216.7 MJ/m²/annum). However, in case study 13 the annual total energy load at the worst orientations exceeded the levels achieved for detached dwelling case study 3.

Comparative energy efficiency of detached and attached dwellings

To examine the comparative energy efficiency of attached dwellings compared with detached dwellings, the case studies were compared with case study 3, the small, brick veneer on slab dwelling, which had a similar internal area to many of the apartments and the most similar constructions. The benchmark for comparison was the AGO finding that attached dwellings were 36 % more efficient on a per square metre basis in comparison with detached dwellings.

Table 4.29 Comparative energy efficiency of attached dwellings

Case study dwelling	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Improved energy efficiency
10	36.9	62.2	99.1	21 %
11	16.5	51.5	67.6	47 %
12	18.4	42.3	60.8	52 %
13	40.3	76.3	116.4	7 %
14	6.8	78.0	84.9	33 %
15	19.1	64.3	83.4	33 %
16	21.2	45.5	77.7	38 %
3 (detached)	17.3	108.5	125.7	comparison

When both the attached and detached case studies were modelled with the same degree of external shielding (heavy), the attached dwellings were more efficient, with the increases in efficiencies ranging from 7 to 52 %, averaging 33 %. In the absence of star ratings, it is difficult to quantify the impact of this variation with any degree of certainty. What can be determined is that the least efficient attached dwelling was case study 13, which had the least area of wall, floor and ceiling spaces shared with adjacent conditioned areas. This would suggest that the more attached dwellings resemble detached dwellings, the higher the annual total loads.

4.6.9 Summary of findings for the thermal programs

In 1999, the AGO noted that

> *The main drawback of prescriptive measures is that, by necessity, they tend to be overly simplistic and are unable to deal with significant areas of energy efficiency (eg passive solar design = orientation and glazing placement) that often require little incremental cost implement during construction (AGO, 1999).*

The conditioned floor area is a result of the zone type selections. As the programs become more sophisticated, more selection possibilities emerge. There is potential for the conditioned floor area to be manipulated to lower the overall energy loads.

At present, the thermal tools are not flexible enough to be used as a design tool as the amount of data that has to be entered as the design progresses, is prohibitive. As a result, the thermal programs are viewed as another compliance hurdle and one that is unsympathetic to local conditions and materials. In addition, passive design is still not a mainstream part of the training of most dwelling designers, who also come from a range of technical and professional backgrounds. Increasing regulations and increasingly complex sites are combining to pressure designers to demonstrate that the dwelling optimizes the site. These issues point to a requirement for thermal programs that are sufficiently sophisticated to be used as a design-optioning tool in the design development phase and preferably, as an integrated CAD tool.

- The external shielding selection affects the energy efficiency. This selection is not disclosed at present;
- The conditioned floor area is a result of the zone type selections. As the programs become more sophisticated, more selection possibilities emerge. Most selections could be argued as being reasonable, but the assessor presents only one set and so comparisons, such as this and others presented throughout these case studies, cannot be made;
- As a result, there is potential for the conditioned floor area to be manipulated to lower the overall energy loads;

- 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 the assessors' objective is to increase the star rating;
- These issues are a function of the use of the programs and not of the programs themselves;
- The ventilation of the under floor area of elevated dwellings needs to be further understood;
- Dwelling designers require a tool to augment passive design principles and enable them to test the energy efficiency of a variety of insulating and shading devices at the design development stage, rather than being forced to react to an inappropriate rating at a later stage;
- Developers require a tool to enable them to maximise the number of appropriately oriented dwellings.

5. LOT RATING TOOL STUDY

In 1999, the Australian Greenhouse Office noted that:

> *Although some states have guidelines for the development of energy efficient subdivisions that provide for good solar access and facilitate correct orientation, this is not mandatory in any state (AGO, 1999)*

One such set of guidelines was developed several years ago by Sustainable Energy Authority of Victoria (SEAV) and was later modified by Sustainable Energy Development Authority (SEDA) (SEDA, 2003). The aim of this Study is to examine this tool to determine the appropriateness of adapting this rating scheme for SEQ.

In southern states, the objective of solar efficient residential design is to limit the solar collector area to that which is sufficient to make a significant reduction in the non-renewable heating energy requirements of living areas

> *A 5 Star lot can save a house up to twice as much heating energy as the same house on a 1 Star lot' (Loder & Bayly Consulting Group with Sustainable Solutions Pty Ltd, 1991).*

In sub-tropical climates, solar access for heating is less important, but orientation still has a critical role in excluding excessive solar gain and increasing natural ventilation.

5.1 SEDA Tool

The SEDA lot rating system takes into account a number of the issues raised by the key informants in Phase One, including;

- Lot size;
- Lot orientation;
- Lot gradient.

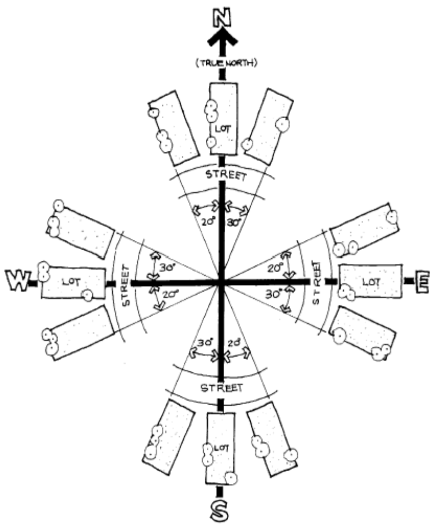
The lots are rated on their ability to accommodate a dwelling with good solar access. The rating scale is 1 to 5 Stars, with 5 Stars being the optimum. The tool applies to separate lots that are between 300-1000m². For lots under 300m², solar access is considered to be more closely integrated with building design and siting. Lots over 1000m² have greater opportunity to achieve good solar access. The slope of the lot will either improve or hinder solar access. Lots with a slope in excess of 20 % receive a 1 Star rating.

Applying the methodology is a simple three-step process:

Step one – determine the orientation

Determine the orientation of a lot along its long boundary. To achieve the highest rating of 5 Stars, the long boundary must be oriented so that one axis is within 30^o east and 20^o west of true solar north, as shown in Figure 5.1. Lots outside these orientations receive a 1 Star rating.

Figure 5.1 Determine lot orientation.



Source: (Commonwealth Department of Housing and Regional Development, 1995)

Step two – determine the lot width

Determine the width of the block by measuring at right angles to the long axis that falls within the acceptable orientation range. East/west lots have a greater width requirement than north/south lots to allow for set back of the dwelling along the northern boundary.

Figure 5.2 Determining lot width

Step three - determine the star rating

Determine the star rating by finding the appropriate width band from Table 5.1:

Table 5.1 Determine the star rating

Table 1 Determining the star rating

Lot orientation	Minimum lot width (metres) Star Rating ★★★★★	★★★★	★★★	★★	★
East/West					
(Coastal NSW)	> 16.2	15.1-16.2	14.2-15.0	13.4-14.1	< 13.4
(Inland NSW)	> 16.8	15.6-16.8	14.4-15.5	13.8-14.3	< 13.8
North					
(Coastal NSW)	>13.5	11.7-13.5	10.9-11.6	10.5-10.8	< 10.5
(Inland NSW)	>14.1	12.2-14.1	11.1-12.1	10.5-11.0	<10.5
South					
(Coastal NSW)	>15.5	13.7-15.5	12.9-13.6	12.5-12.8	< 12.5
(Inland NSW)	>16.1	14.2-16.1	13.1-14.1	12.5-13.0	<12.5

TABLE 1
USE THIS TABLE IF THE HEIGHT OF BUILDINGS TO THE NORTH IS NOT LIMITED.

Definitions
East / West: Bearing of one long side within 250 and 300º, street on east or west side
North: Bearing of one long side within 340 and 30º, street on southern side
South: Bearing of one long side within 340 and 30º, street on northern side, note that greater lot widths are to allow for car access to north.

It will be noted from Table1 that reducing lot width results in a reduction in the solar access star rating. This need not be the case. Lot width can be reduced without impacting on the solar access rating by placing height restrictions to houses on the north boundaries.

Source: (SEDA, 2003)

5.2 Case Study Selection

The objective was to trial the SEDA lot-rating tool to assess its appropriateness for SEQ. This phase of the study examined four sub-divisional layouts provided by the Project Partners. The outcomes of this Study were then integrated with the dwelling rating tool to determine if the correlation between lot rating and dwelling ratings is as significant as that found in the southern states. The detailed case studies are at Appendix B. A summary of the findings follows.

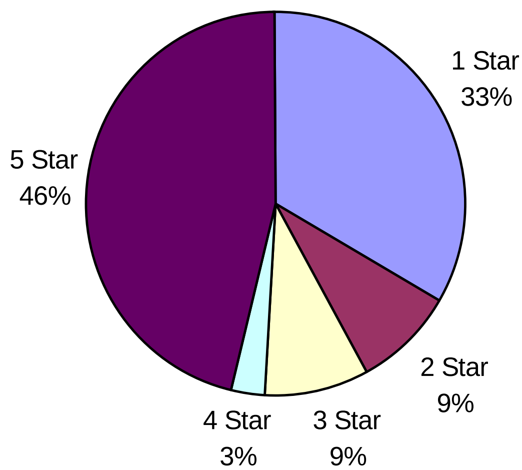
5.2.1 Case study 1

This sub-division consists of:

- 71 lots;
- Size range 300m² - 1000m² - (average 520m²)
- A range of display dwellings including the GreenSmart village sites

Figure 5.3 Sub-division case study 1

Figure 5.4 Star rating case study 1



Of the 69 lots surveyed, 33 % of lots within the sub-division rated at one star, while 46 % rated at the maximum 5 Star (Figure 5.4). SEDA in their design guidelines, aim for performance criteria of at least 80 % of lots rating 5 stars with the remainder rating either 4 or 3 stars. This initial finding suggested that current sub-division practice is falling well short of the mark.

In this sub-division, 34 lots, or nearly 50 %, of the 71 dwelling sites are small, (under 450m^2) and of these, only 2 achieved 5 Stars. Only one lot was very large (over 1000 m^2) and none was over 20° in slope. The high percentage of small lots, coupled with the Phase One key informants identifying increasing densities in Greenfield developments as an issue, triggered an examination of the impact of increased external shielding in the next study.

A further three SEQ subdivisions were trialed using the SEDA methodology.

5.2.2 Case study 2

Case study 2 consisted of:

- 46 lots;
- Size range 707m^2 - 1535m^{2-} (average 923m^2);
- All large lots (over 560m^2).

Figure 5.5 Sub-division case study 2

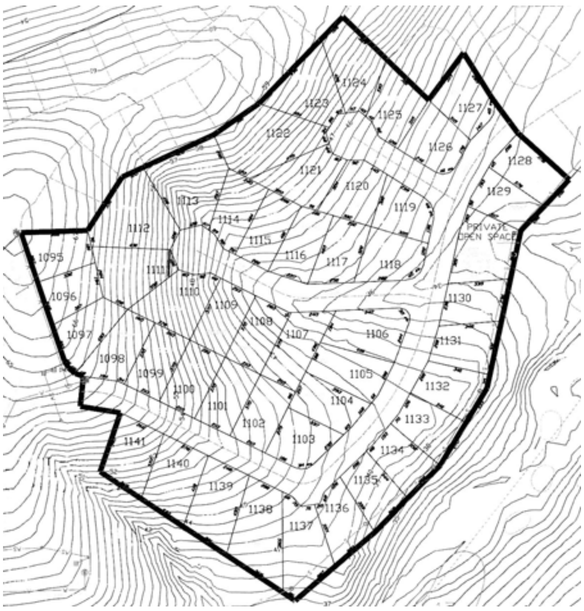
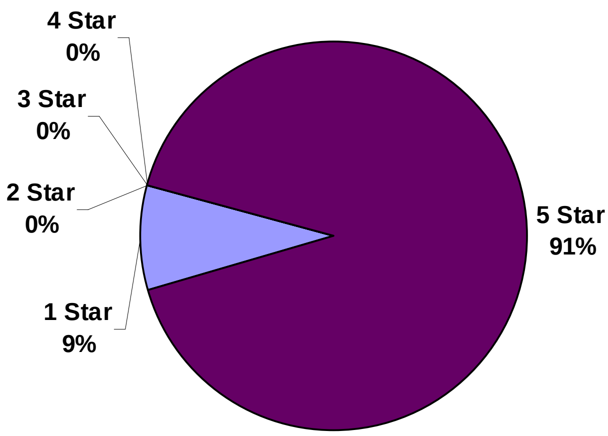


Figure 5.6 Star rating lots case study 2



This sub-division complies with the SEDA guidelines with 91 % achieving 5 Stars. With an average lot size of 923m^{2,} these are all large lots and 12 lots (26 %) were over 1000m^2 and automatically achieved 5 Stars as, according to SEDA, lots over 1000m^2 have greater opportunity to achieve good solar access. The 1 star ratings were due to inappropriate orientation and not due to steep slope.

5.2.3 Case study 3

- 36 lots;
- Size range 780m^2 - 980m^2 (average 890m^2);
- All large lots (over 560m^2).

Figure 5.7 Sub-division case study 3

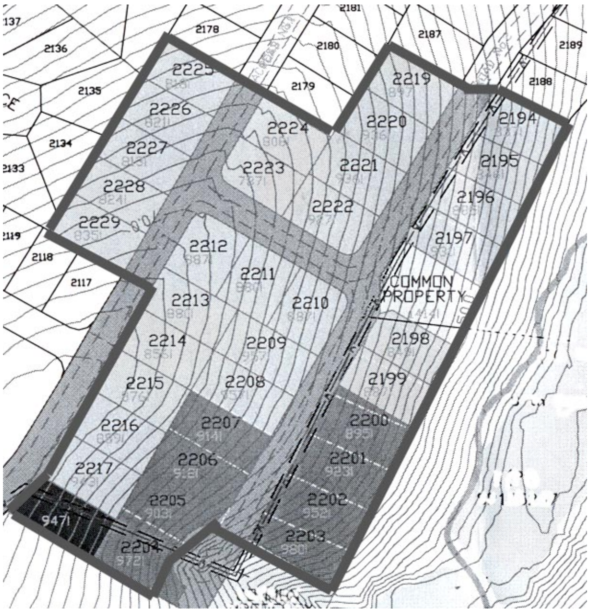
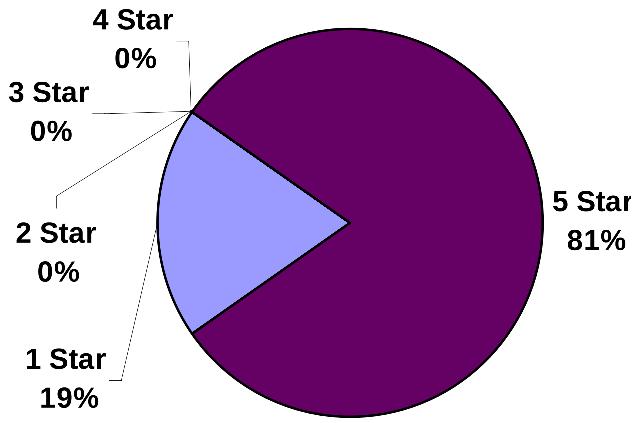


Figure 5.8 Star rating case study 3



This sub-division also complies with the SEDA guidelines, with 80 % of the lots rating 5 Stars. The only sites that did not score 5 Stars were seven steep lots (over 20°), which automatically achieved 1 Star. According to SEDA, the slope of the lot will either improve or hinder solar access. According to the key informants, steep gradients will limit the type, size and orientation of dwelling that can be constructed within a lot. Much of the steep topography is not compatible for construction and is suited only for landscaping

5.2.4 Case study 4

Case study sub-division 4 consists of:

- 65 lots;
- Size range 815m² - 1302m² (average 981 m²);
- All large lots (over 560m²).

Figure 5.9 Sub-division case study 4

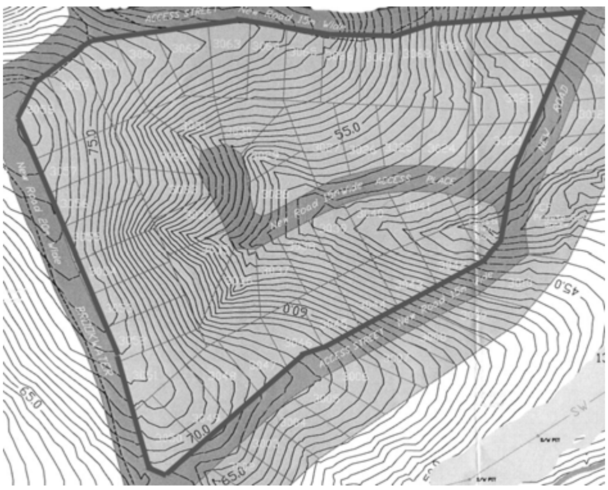
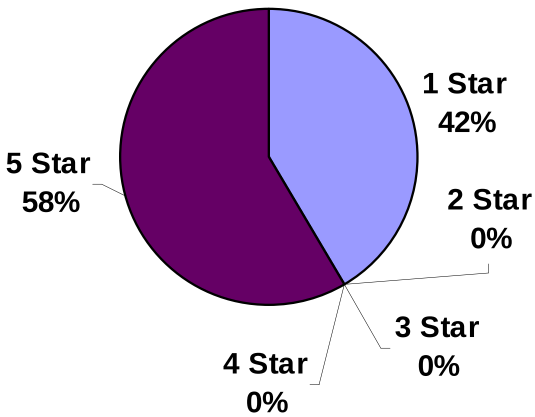


Figure 5.10 Star rating case study 4



This later release has the largest average lot size of 891 m² and is set on steeply sloping topography as evidenced by the site map in Figure 33.

With only 58 % achieving 5 stars, this development does not comply with the SEDA guidelines. Twenty lots (30 %) are over 1000m² and automatically achieve 5 Stars. Four of these lots are over 20° in slope and are rated at 1 Star in recognition of the difficulties inherent in designing energy efficient dwellings on steep slopes. The other 1 star lots were oriented outside the SEDA guidelines. In this steeply sloping development, the lot orientation has been constrained by the site topography.

5.3 Relevance of Tool to SEQ

The following summaries the findings from the case studies under the issues highlighted by the key informants in Phase One of this project.

5.3.1 Topography

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 or slab construction. For the purpose of this study, lot slope was only identified when it exceeded the 20° and affected the star rating but the number of sloping sites can be readily identified from the contour lines on the case study sub-division maps.

5.3.2 Orientation

The concern is that this tool focuses on orientation for solar access, which is the focus in the southern states. In Queensland, the focus is on limiting solar gain in summer and increasing access to natural ventilation.

The quantitative analysis of energy-efficiency of dwellings and their relation to sub-division requirements took advantage of new capabilities to assess appropriate ventilation in determining the energy performance of dwellings, particularly in the sub-tropical climates. It also took advantage of new capabilities to assess the impact of external barriers in blocking natural ventilation.

5.3.3 Lot size

Case study 1 has the highest proportion (50 %) of small lot sizes, the lowest average lot size (520 m²) and the lowest percentage (46 %) of 5 star lots. This high percentage of small lots, coupled with the Phase One key informants identifying increasing densities in Greenfield developments as an issue, triggered an examination of the impact of increased densities in the energy efficiency study.

At the other end of the scale, case study 4 had the largest average lot size (981 m²) the largest percentage of very large lots (30 %), yet had the second lowest percentage (58 %) of 5 star lots due in part because of constraints imposed by the topography.

5.3.4 Lot density

Sub-divisional density is a product of the average lot size and implies decreased opportunity for natural ventilation. The focus for density follows that described for lot size.

At the very least, the tool provides a numerical indicator of the number of sites that are likely to require more intensive design solutions and could be used to re-examine the layout to assess alternative patterns.

5.4 Additional Criteria for a Lot Rating Tool in SEQ

One of the conclusions from Phase One of this study stated:

> *Tools that measure energy efficiency need to be site specific, across the whole of the industry and take into account factors such as orientation, adjacent built forms, deciduous and evergreen vegetation, and a broad range of construction materials.*

To determine if the SEDA tool meets these general requirements and is appropriate for SEQ, the project utilised the case study dwellings to test the correlation between lot rating and dwelling energy efficiency. The project took advantage of a new thermal analysis tool, AccuRate, which takes into account not only the built form, but also site specific criteria such as orientation, ventilation and external barriers that reduce ventilation.

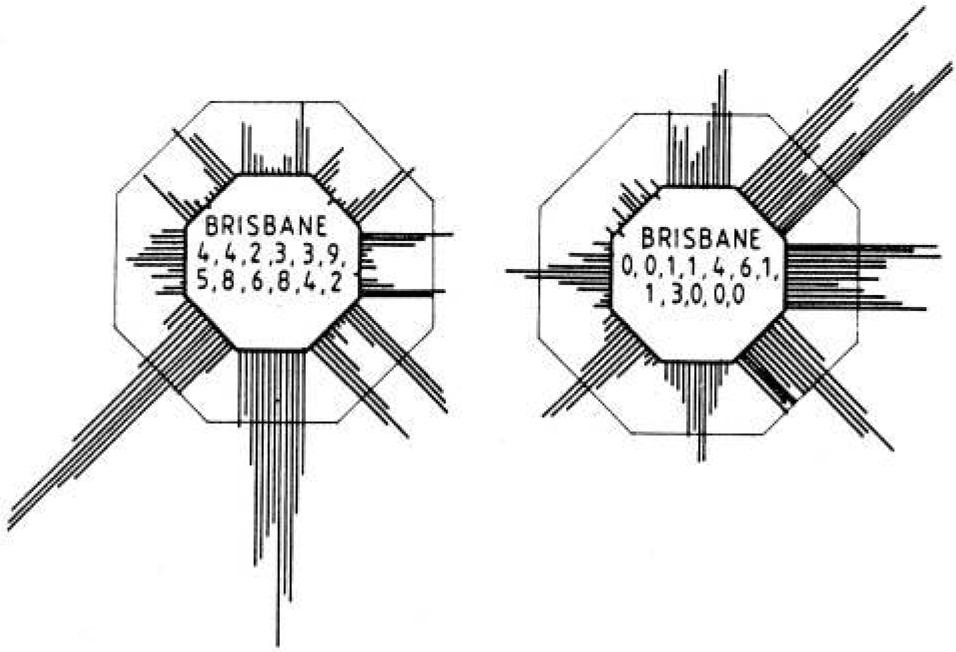
As revealed in the case studies, the effect of external barriers, shielding and ventilation play an important part in the overall comfort levels that each dwelling is able to achieve. Consequently, it is important that any lot-rating tool for SEQ attempt to take these factors into consideration when assessing a particular lot.

5.4.1 Assessing breeze access

The lot-rating tool as it currently exists assesses only the solar orientation of the lot to maximise solar gain. The effects of ventilation are not considered and this is an important aspect in SEQ. The ability of a house to capture breezes is directly linked to the orientation of the house and thus like solar orientation, the orientation of the lot can be used to determine how well it is sited to capture those breezes.

Figure 5.11 shows two wind roses for Brisbane, one for 9am (left) and 3pm (right). These roses have eight sides corresponding with the four cardinal and four semi cardinal points of the compass, giving directions from where the wind comes from. Each side has twelve lines, corresponding to the twelve months of a calendar year in a clockwise direction. The outer octagon defines the scale: 12.5 %, i.e., if the wind were evenly distributed, coming from all eight directions with the same frequency, all lines would be this length. The twelve numbers inside the octagon indicate the percentages of calm for the twelve months in sequence (Szokolay, 1988).

Figure 5.11 Brisbane wind rose for 9AM and 3PM



Source: (Szokolay, 1988)

For Brisbane the important times to receive breezes are during summer afternoons to aid in the cooling process. The 3pm wind rose shows that these breezes are strongest and most frequent from the north-east, and the east and south-east to a lesser degree. Consequently, it is important that dwelling design take this into consideration and lots that allow for this should be rewarded accordingly in any rating tool.

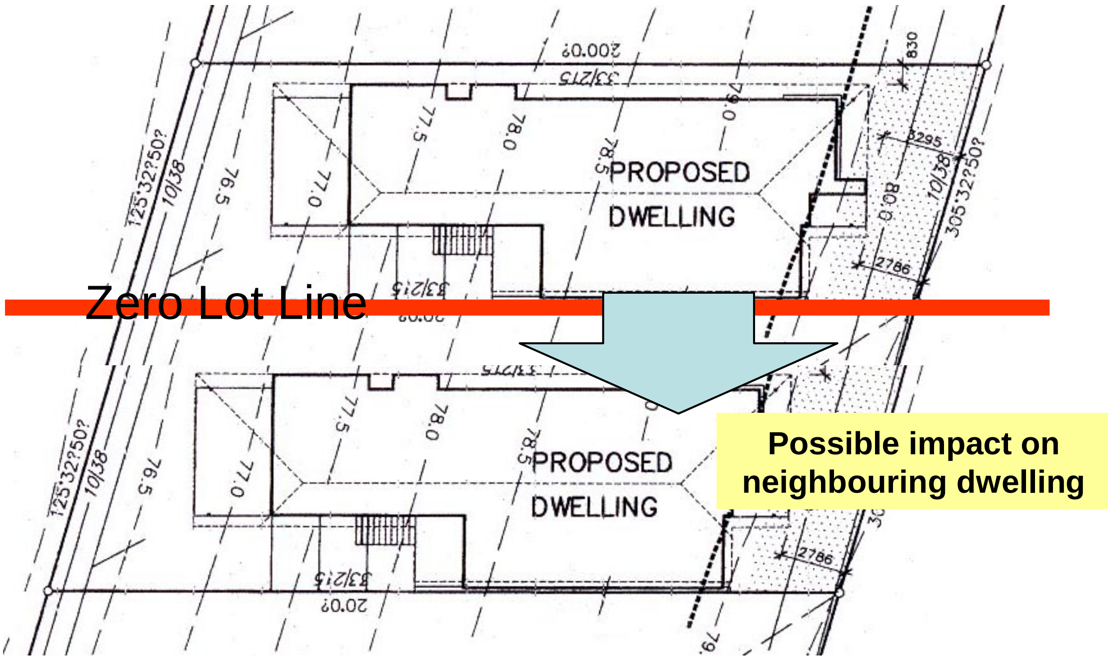
However, care must also be taken with the width of the lot. Narrow lots that are likely to have another dwelling in close proximity will have their ability to capture breezes reduced, so this would also need to be considered with narrow lots likely to be penalised.

5.4.2 Assessing shielding

The case studies have also indicated that shielding is an important factor in the overall performance of a dwelling. Shielding from buildings in close proximity to a dwelling being rated has a significant effect on its ventilation capabilities and it is this effect that 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 zero lot line lots.

Zero lot line lots tend to be narrow lots 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 would have on any other lot should be taken in consideration. As shown in Figure 5.12 neighbouring dwellings can be close, indeed it has been observed that some dwellings are separated by less than a metre and would greatly reduce the ability to capture breezes or sunlight for either dwelling along those shielded walls.

Figure 5.12 Zero lot line example



5.4.3 Weighting factors

Creating the need to assess multiple criteria, i.e. solar gain/protection, breeze access and shielding potential, requires the need to determine the impact that each of these criteria will have on the overall performance of a particular lot. Once the respective level of impact has been determined, then 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 factors 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 in the southern states for which the initial lot rating tool was developed, and it is understandable that such criteria were not considered for these areas. It is often assumed that ventilation is the more important driver in SEQ when it comes to dwelling design, but solar orientation is just as important for delivering effective solar protection in SEQ 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 see the detrimental effects in their design rating.

5.4.4 Linking to other systems

One of the barriers to effective utilisation of analysis and evaluation tools 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 tools.

Land sub-division is nowadays aided by the use of sophisticated tools such as Geographic Information Systems (GIS). GIS data used for land sub-division would usually contain the vast majority of 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.

6. ON-SITE ELECTRICITY GENERATION STUDY

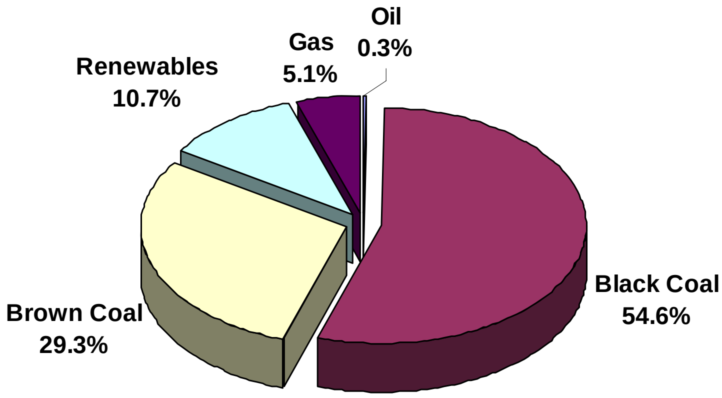
Sufficient sunlight falls on Australia to provide the nation's total energy needs.
Australian Greenhouse Office

This phase of the project focused primarily on examining the energy efficiency of a range of dwellings by examining the energy used to heat and cool. It also assessed the appropriateness of developing a lot rating tool aimed at reducing energy consumption at dwelling and sub-divisional levels. There is potential at both these levels to generate electricity and this report will now explore the technologies available for on-site electricity generation.

6.1 Energy Generation

The vast majority of Australia's electricity generation is sourced from large-scale fossil fuel fired power stations and delivered to consumers through an extensive national power grid as shown in Figure 6.1. Consumers unable to access the grid (usually in remote areas) have traditionally produced their own electricity using diesel or petrol generators. However, recently many remote communities have started to incorporate alternative, renewable electricity generation because of increasing fuel costs, improvements in the efficiency of renewable energy systems and the increasing affordability of renewable electricity systems.

Figure 6.1 Electricity generation by fuel type



Source: (Roarty, 2001)

Despite the advancements made in renewable energy generation, it is very rarely used in urban environments where access to the national grid is available. However, communities and developers are now looking at ways that this technology can be incorporated into their areas to help reduce the environmental impact that traditional electricity generation causes.

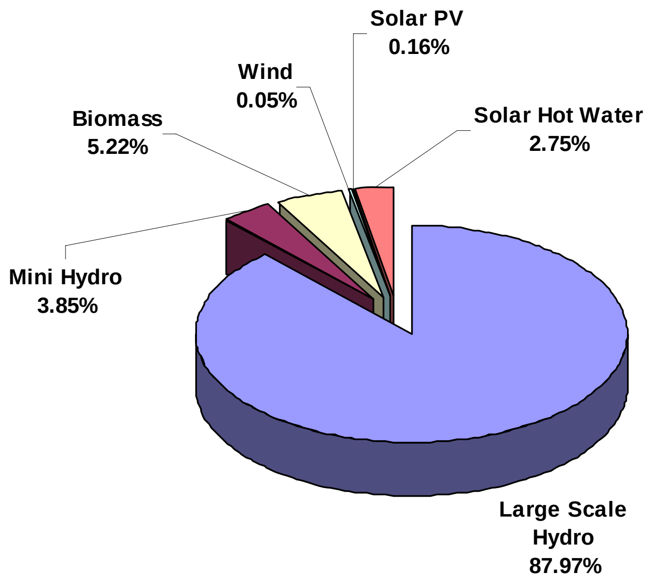
6.2 Renewable Energy

Australia's dependence on large fossil fuel power stations has resulted in the majority of greenhouse gases that Australia produces coming from these power stations, accounting for around 85 % of the nation's total greenhouse gas output. Over the last few years there has been a push to increase the amount of electricity produced from renewable sources, such as wind and hydro, but renewable energy systems have found it difficult to compete against the relatively cheap fossil fuel generators. This is especially true for small renewable energy plants.

Figure 6.1 shows that 10.7 % of Australia's electricity comes from renewable sources. However, the vast majority of this is from large-scale hydro power stations located predominantly in Tasmania. These power stations account for almost 88 % of renewable electricity generation (see Figure 6.2) with the remaining renewable energy sources accounting for only 1.3 % of the nation's electricity generation. It is interesting to note too that this value is slightly inflated as it also includes solar hot water as a renewable energy source whereas in reality these systems do not produce electricity. The contribution is based on the electricity saved by not using fossil fuel derived electricity as the alternative for heating the water.

The renewable energy industry has relied on Government subsidies and compulsory minimum renewable energy targets set by the Government. The renewable energy target scheme imposes a legal obligation on electricity retailers and other large electricity customers to source an additional 2 % of their electricity from renewable or specified waste-product energy sources by 2010. This, in effect, is more than doubling the current renewable energy market, as it is highly unlikely that any large-scale hydro power stations will be constructed in the near future. The objective of the scheme is to reduce emissions of greenhouse gases and encourage the development of a renewable energy industry in Australia.

Figure 6.2 Electricity generated by renewable energy sources



Source: (Roarty, 2001)

Consumers wishing to source their electricity from renewable sources have several options available to them. The simplest option is for consumers to select the "green power" option from their current electricity provider; but this option is only available to individual consumers. For developers wishing to incorporate a renewable energy component into a development the only real option is to include on-site energy generation.

On site electricity generation has traditionally used diesel/petrol generators, but of course these still use non-renewable fossil fuels as their fuel source. Renewable on site electricity generation utilises natural sources that are continuously replenishing, such as sunlight, wind and water.

6.2.1 Solar

Solar energy is using sunlight as the energy source and the most common devices are photovoltaic (PV) modules. PV cells have no moving parts and consequently are highly reliable and virtually maintenance free. They are popular in urban environments as they can be easily fitted to existing roofs, generally lie flat (so they are unobtrusive) and make no sound. However, panels are expensive and arrays large enough to provide the electricity needs for a typical household may have long payback periods.

6.2.2 Wind

Large-scale wind generators have been in the news lately in Australia with many people opposed to the dominance these structures have on the landscape. Certainly, as these wind generators require reliable, strong winds, they are often sited along coastal areas and dominate the landscape. However, schemes such as the Codrington wind farm in Victoria (Figure 6.3) produce 18.2 megawatts of electricity from the fourteen wind turbines, enough electricity for 11,000 dwellings and do represent one of the most cost effective forms of renewable energy production.

Figure 6.3 Codrington wind farm, Port Fairy, Victoria

Source: (Pacific Hydro Limited, 2004)

For urban environments, large wind turbines are not really an option, but small scale generators have been available for many years. These have been mainly used in remote areas to charge battery banks, and have generally been regarded as unsuitable for urban areas due to the need for a relatively tall tower (ten to twenty metres) to capture clear wind and the noise levels produced from the turbine. However, a new generation of vertical axis turbines has been developed specifically for urban areas and these may allow wind power to be harnessed for urban communities.

6.2.3 Hydro

Hydro electricity was the first renewable energy source employed and still represents the vast majority of renewable energy production in Australia. Most of this is from large-scale hydro power stations in Tasmania and in the Snowy Mountains, but micro hydro systems also exist and actually represent a significant proportion of small-scale renewable energy generation in Australia.

As with large-scale systems, micro hydro units convert the energy of flowing water into electrical energy. The systems are relatively simple with the water turning a wheel or a runner to rotate a turbine. Naturally, such systems are really only useful where there is a continual supply of running water and where the static head (the vertical distance between the water intake and where the water enters the generator) is sufficient. Generally, such conditions are hard to come by in urban environments and as such, mini hydro systems are considered impractical.

6.3 Photovoltaic Modules

Electricity generation direct from sunlight has long been considered the ultimate answer to the world's energy needs. In Australia alone enough sunlight falls on the continent to provide for all electricity needs. Turning the dream into reality has been difficult with the available systems being very expensive to initially purchase and with low efficiency, resulting in the need to have large arrays to provide all the energy requirements.

The most common form of these panels are the stand alone systems that are placed on roof tops, but recent developments have seen panels that are integrated into the building fabric coming onto the market.

6.3.1 PV Panels

Traditional PV panels have been available for many years and are usually either a crystalline silicon system or an amorphous silicon thin film system.

Crystalline modules are covered with tempered glass on top and tough ethylene vinyl acetate (EVA) material at the back. The glass and backing material protect the solar cells from moisture. Ironically, as crystalline modules heat up, their efficiency reduces by about 0.5 % per degree Celsius above 25°C, so it is important that they are kept cool.

Amorphous silicon cells can be applied as a thin film to various substrates such as glass and plastic making them highly versatile and suitable for large applications.

Installation

Naturally, solar panels are most efficient when pointed directly at the sun and ideally should be in full sun from 9am to 3pm in mid winter. In Brisbane the mean daily sunshine hours available varies from 6.7 hours in February and March to 8.3 hours in September, November and December, as shown in Table 6.1.

Table 6.1 Mean daily sunshine hours for Brisbane

Month	Sunhours	Month	Sunhours
January	7.7	July	7.3
February	6.7	August	8.0
March	6.7	September	8.3
April	7.3	October	8.2
May	7.0	November	8.3
June	6.8	December	8.3
Annual 7.5			

Source: (Bureau of Meteorology, 2004)

The angle at which panels should be installed for a grid-connected system is the latitude minus 10 degrees to maximise the amount of energy produced annually. For Brisbane this would result in an optimal angle of 19 degrees (28 less 10). This is a slightly shallower pitch than is common, but still within what is considered an acceptable roof pitch angle and means that the panels can sit flat against the roof surface.

The output from solar panels is rated in kilowatt peak (kWp) and for a 1kWp array in Brisbane the annual load in kilowatt-hours should be around 1500kWh. The average Brisbane household's electricity usage for a year is around 5000kWh, but with energy efficient appliances, non-electric heating/cooling, cooking, and hot water, it is quite possible that this size array could provide a household's annual electricity requirements.

Case studies

Many individual examples exist of PV arrays fixed to residential buildings. Figure 6.4 shows a typical installation on the QDPW research house in Rockhampton.

Figure 6.4 Traditional PV panels on the Rockhampton research house

Source: (Author photograph, 2004)

6.3.2 Building Integrated Photovoltaic (BiPV)

Traditional PV panels are separate systems that a placed on top of an existing surface, usually the roof. However, PV systems are now available that are integrated into the building design and serve a dual purpose of producing electricity and being part of the building fabric. Such systems can be part of the façade, roof, skylights or awnings and help offset the initial cost of PV arrays. In fact, BiPVs are now one of the fastest growing PV markets worldwide (Watt, Kaye et al., 1997).

Like standard PV panels, BiPV systems have individual solar cells interconnected and encapsulated in various materials to form a module. Modules are strung together in an electrical series with cables and wires to form a PV array. A wide variety of BiPV systems are available in today's markets. Most of them can be grouped into two main categories façade systems and roofing systems. Façade systems include curtain wall products, spandrel panels, and glazing. Roofing systems include tiles, shingles, standing seam products, and skylights (Eiffert and Kiss, 2000).

In Australia, façade systems are generally considered to be uneconomical as the efficiency of the panels is greatly reduced due to the high sun angles we experience (especially in northern cities like Brisbane), resulting in PV output from walls being typically one third or less than roof output per unit area (Watt, Kaye et al., 1997).

Installation

As BiPV systems serve dual purposes, it is essential that careful design and installation be carried out. To help with this process, guidelines on best practice for the incorporation of Building Integrated Photovoltaics in Australia have been developed. The guidelines distinguish, within clearly identifiable sections, information relevant to different stakeholders from BiPV project design conception through to installation, commissioning, monitoring and disassembly (Snow, Prasad et al., 2004).

The guidelines state that:

> *PV is still a very new technology to the Australian building industry with only a few companies having first hand experience through BiPV showcase project implementation. Building construction, even without PV, is a multi-faceted process requiring detailed construction scheduling to ensure building materials arrive on time and tradesmen, often sub-contractors, operate in a co-ordinated sequence. The same applies when adding BiPV. Good practice includes roofers, cladding tradesmen and PV installers using the same scaffolding. BiPV may be assembled off site and needs to be packed and labelled appropriately prior to transportation so that the unloading happens in a methodical way,*

particularly if construction site space is limited. Similarly, installation of PV and completion of construction work thereafter can be scheduled from the top down so that there is minimal risk of unsecured objects falling and breaking PV surfaces below.

Different PV products require attention to safety and care during the installation process and tradesmen should be appropriately briefed to avoid costly damage or accident. PV mounting and installation instructions are normally made available by the manufacturer but usually the qualified person responsible for the PV installation will oversee this phase in close liaison with the site manager. On-going consultation with the project architect is also essential, especially if building modifications such as additional roof penetrations are included post design, to avoid compromising the solar access of PV surfaces.

Case studies

BiPV use in Australia has been limited to several showcase projects. One such project is the new CSIRO Energy Centre in Newcastle. This centre incorporates three different kinds of photovoltaic cells generating about 90 kW of electricity; two of these systems are BiPV systems. Mono-crystalline cells are used as roof tiles on the laboratories, offices, and library; and titania solar cells are used on the western face of the southern plant building. These titania cells do not need direct exposure to sunlight. The third system is traditional polycrystalline cells and is clipped onto the auditorium roof.

Figure 6.5 shows one of the mono-crystalline BiPV systems installed over the library area. As can be seen the combined roofing/PV system provides abundant natural light to the interior space, which can be reduced by drawing blinds as shown in the right hand image. In fact, so much natural light is available that the lights have only ever been switched on at night. This is an excellent example of how BiPV systems can be utilised with the system providing a roof cover, natural lighting system and generating electricity.

Figure 6.5 CSIRO's Energy Centre with one of the BiPV solar cell systems installed above the library

Source: (Author photograph, 2004)

For residential buildings the best-known Australian example is the former Sydney Olympic village in the suburb of Newington, see Figure 6.6. This is one of the world's largest solar powered suburbs with twelve PV cells installed on the roof of every house in the former village (665 dwellings), along with a gas boosted solar hot water system. The PV cells have the capacity to generate one million kilowatt hours of electricity per year, equivalent to the energy needs of all 2000 houses in the suburb (Reed, Spooner et al., 2001). The system is actually a hybrid between a traditional panel system and a BiPV system and is partially integrated into the roof structure using a special mounting structure to hold the cells, but requires an additional waterproof layer (Reardon, 2001).

Figure 6.6 Partially integrated PV array at Newington

Source: (Taylor, 2000)

6.4 Co-generation

The problem with many renewable energy systems is that the source of energy is not available 24 hours a day, every day of the year. Solar systems only operate effectively on sunny days and wind generators will only work on windy days. For many systems that are connected to the grid, this is not a problem and the grid provides power when the renewable system cannot. In remote areas, or where a disconnected system is preferred, a backup energy source will usually be required. The most common form of a co-generation system in residential buildings is a solar hot water system, which will usually either have an electric or gas booster system installed for when the solar system cannot provide enough energy to heat the water. However, similar systems are available for electricity generation systems.

6.4.1 Solar/gas

Large-scale solar thermal electric technologies utilise concentrators to focus sunlight to heat a working fluid that is then used to drive conventional steam power plant equipment. Supplemented with gas-fired boilers, these systems can be used to deliver power over a 24-hour period. To date some 354 MWe have been installed in California.

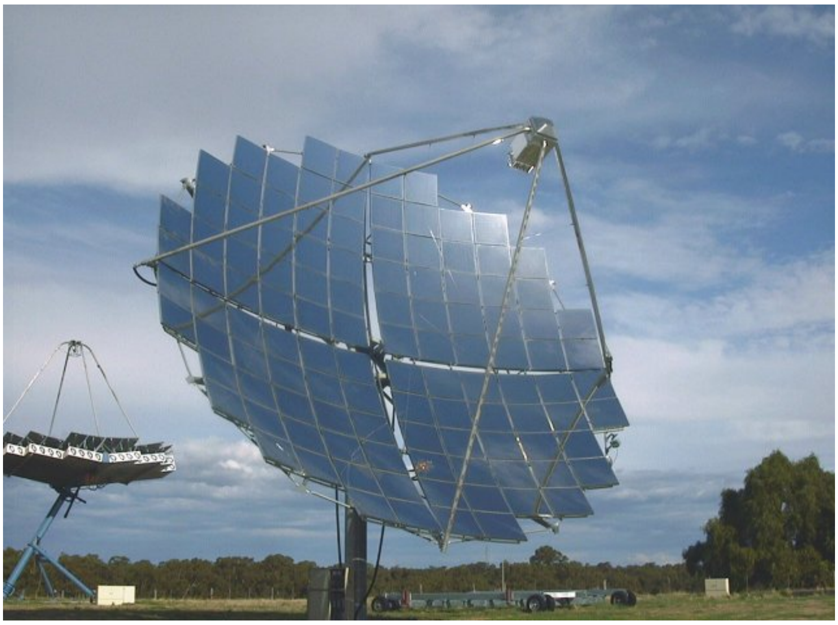
Smaller scale solar thermal electric plants could potentially contribute to community based power systems that support a mini-grid. Principal contenders here would be parabolic dish Stirling or Brayton cycle systems, which have been designed and demonstrated at kW rather than MW sizes. Such systems have demonstrated extremely high solar to electricity conversion efficiencies (greater than 29 %), and can generate AC power directly. The Stirling-engine generator unit also has the potential to be powered using gas or biomass, see Figure 6.7.

Figure 6.7 Stirling parabolic dish at Arizona Solar Centre

Source: (Arizona Solar Centre, 2004))

In Australia, Solar Systems have developed a different system comprising a sun-tracking parabolic dish reflector and a high power solar cell bank as shown in Figure 6.8. The sunlight, which shines on the reflector mirrors, is focussed to the cell bank in the receiver where it is converted directly to DC electricity. A matched inverter is used to produce 20 kWe of standard 3 phase, 415 Volt AC power at the output terminals. The unit can be configured for connection to thermal cogeneration plants (Solar Systems, 2004).

Figure 6.8 Solar System's solar electric power generator



Source: (Solar Systems, 2004)

6.4.2 Non-renewable Co-generation

Many industries already utilise co-generation systems, but the majority of these do not use a renewable energy source. Nevertheless, such systems are often worth considering as an economical form of energy use. The most typical systems use a gas-fired turbine that generates electricity with the heat generated from the combustion process being used to heat water or produce steam. Many hospitals use such systems, with the steam produced being used in their laundries.

Micro turbine systems are also available which could have the potential in residential developments to provide electricity and hot water requirements. Medium and high-rise developments would be well suited to such systems. Figure 6.9 shows a typical micro co-generation turbine that uses natural gas as its energy source with by-product heat being used to heat water and provide air heating to an office complex. This unit is capable of producing 75kW of electricity, is freestanding, is about the size of a refrigerator and has low greenhouse gas emissions compared to traditional energy generation sources.

Figure 6.9 Typical micro co-generation turbine installed at the CSIRO Energy Centre

Source: (Author photograph, 2004)

6.5 Solar Thermal

Although solar thermal systems do not produce electricity directly, they are a very important part of reducing the overall electricity consumption of dwellings by shifting traditional electricity powered operations to solar thermal operations. The most common solar thermal system is a solar hot water unit, but solar thermal systems can also be used to heat and cool dwellings.

6.5.1 Solar Hot Water

Solar hot water (SHW) units have been available for decades and are probably the best known use of solar power for dwellings. Traditional hot water services that use either electricity or gas can account for 30 % of a households total greenhouse gas emissions, whereas, solar hot water can provide up to 90 % of a households hot water requirements, depending on the type of system and the climate it is located in (Reardon, 2001). Most systems use a series of solar panels that absorb energy from the sun, which then heats water as it passes through the panels. The resulting hot water is then stored in an insulated tank.

Installation

There are several variances available for SHW units including whether they are passive or active systems, the location of the storage tanks and what type of booster they use.

Passive systems have the storage tank placed above the solar panels, utilise a thermosiphon system to circulate water with cold water travelling down through the panels and once warmed, passing back up to the tank. This eliminates the need for a pump, thus saving energy and reducing maintenance costs. The most common form of passive system is the closed-coupled system, which has the tank mounted directly above the panels and uses mains pressure water, see Figure 6.10. The other passive form is a gravity-feed system which has the tank stored in the roof cavity, but household plumbing must be designed to deal with gravity fed water (Reardon, 2001).

Active systems can have a storage tank located below the panels, usually on the ground, and use a pump to circulate the water. The advantage of this is that panels can be mounted flush with the roofline reducing the visual impact. However, they are usually more expensive to purchase, have higher maintenance costs and are often not as efficient as passive systems.

Although SHW systems are very effective, most will not be able to meet a households total hot water needs during the winter months thus a hot water booster will usually be required. Two main types are available, either electric or gas. Most modern SHW systems will control the need for the booster automatically, although manual override is usually available. Electric boosted systems do produce more greenhouse gases, but are often cheaper and in climates like Brisbane where SHW systems will be able to provide the vast majority of hot water without boosting; the additional expense of gas boosted may not be warranted.

Figure 6.10 Solar hot water system installed at the Rockhampton research house

Case studies

There are numerous examples of solar hot water systems being incorporated into residential developments. Most of these are relatively small scale with around 10 or 20 dwellings all having solar systems installed. However, a development that is currently being built in Queensland will boast 400 dwellings all with solar hot water systems provided with the land purchase and required to be installed, along with a range of other energy efficient measures being mandatory. Sanctuary Pocket is being developed by one of Australia's largest urban land development companies and is being seen as a test case for their future developments, with the developers considering making solar hot water systems mandatory on all their future developments.

Figure 6.11 Sanctuary Pocket development under construction

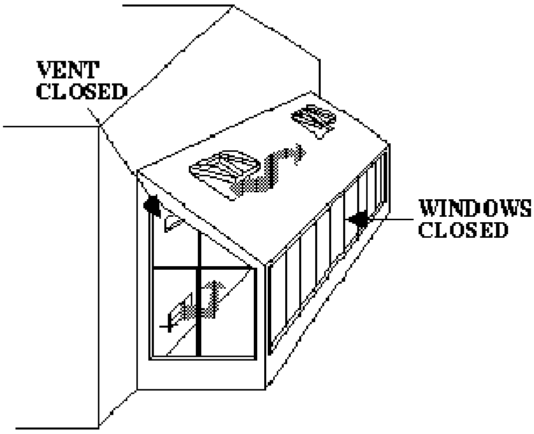
Source: (Author photograph, 2004)

6.5.2 Thermal Chimneys

In benign climates, like Brisbane's, energy consumption for heating and cooling is relatively small (around 6 %) and a well designed dwelling should have no real need for mechanical heating or cooling devices (Reardon, 2001). However, systems such as solar or thermal chimneys can help in the heating/cooling process and can be well suited to medium or high-density apartment blocks for heating and cooling common areas.

A thermal chimney employs convective currents to draw air out of a building. By creating a warm or hot zone with an exterior exhaust outlet, air can be drawn into the house, ventilating the structure. Sunrooms can be designed to perform this function with the excessive heat generated in a north facing sunroom being vented at the top and with the connecting lower vents to the living space open along with windows on the south side. Air is drawn through the living space to be exhausted through the sunroom upper vents, see Figure 6.12 (Sustainable Sources, 1994).

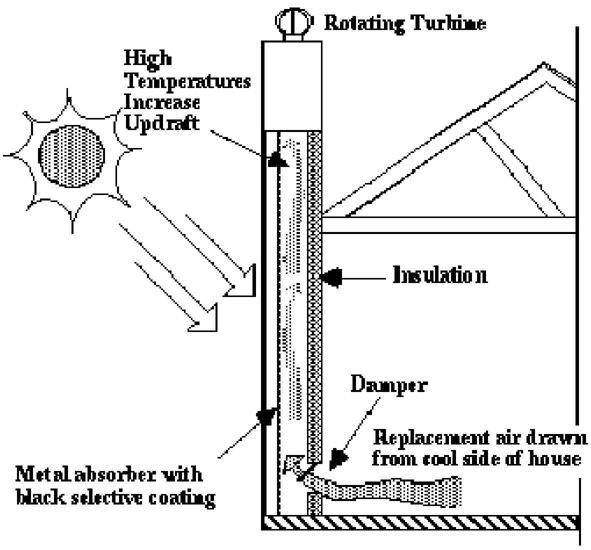
Figure 6.12 Summer Venting Sunroom



Source: (Sustainable Sources, 1994)

True thermal chimneys can be constructed in a narrow configuration (like a chimney) with an easily heated black metal absorber on the inside behind a glazed front that can reach high temperatures and be insulated from the house. The chimney must terminate above the roof level. A rotating metal scoop at the top, which opens opposite the wind, will allow heated air to exhaust without being overcome by the prevailing wind.

Figure 6.13 Thermal chimney



Source: (Sustainable Sources, 1994)

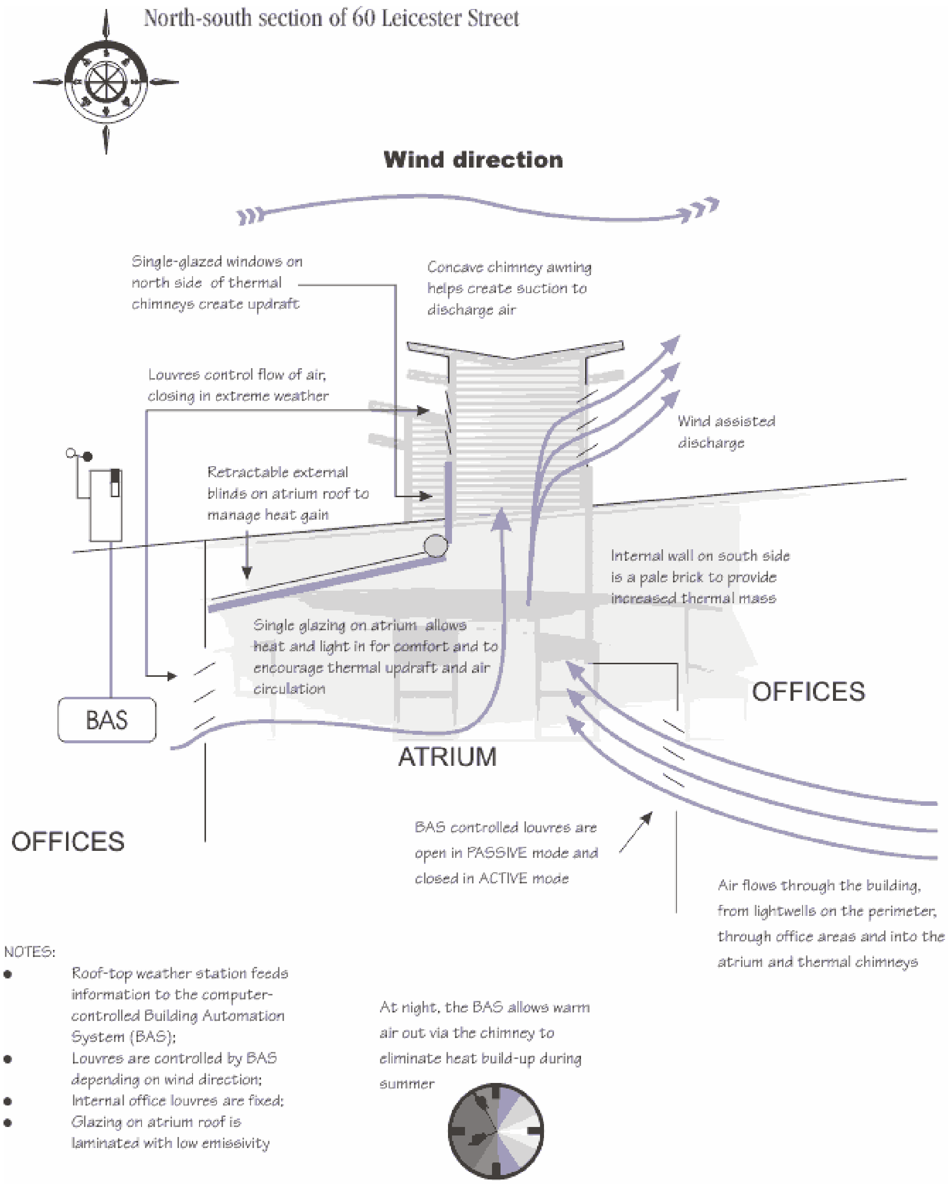
Thermal chimney effects can be integrated into the house with open stairwells and atria and this approach can be an aesthetic plus to the dwelling as well.

Case study

One of the best recent examples of thermal chimney technology in Australia is the 60L building located in Melbourne. 60L is regarded as one of the premier green commercial buildings in Australia, and is unique in its approach to energy and water consumption, and the use of recycled and re-used materials during construction. One of the key features of the building is the use of the thermal chimneys that allow natural circulation of air throughout the building, as shown in Figure 6.14.

The 60L green building has two operating modes: passive - when the internal temperature is between 19-26C air flow is controlled by the computerised louvre system and by tenants opening or closing windows accordingly; active - when the building temperature is above or below the 19-26C band, active heating or cooling can be operated by tenants (60L, 2004).

Figure 6.14 60L thermal chimney operation



Source: (60L, 2004)

Figure 6.15 60L thermal chimneys

Source: (60L, 2004)

6.6 Wind Turbines

Large-scale wind farms currently provide a very small contribution to the national grid, although this is increasing as more farms are currently being established across Australia. Due to their size, these wind turbines are unsuitable for urban areas and until recently small wind turbines were also considered unsuitable due to their height requirements and their relatively noisy operation.

The two main types of wind turbines are:

- Horizontal axis wind turbines (HAWT), and
- Vertical axis wind turbines (VAWT)

HAWTs have been by far the most dominant form of turbine due to their high efficiency, greater output and relatively lower price compared to VAWTs. However, recent development of a new generation of VAWTs has provided the possibility of including wind energy in urban areas.

6.6.1 Vertical axis wind turbines (VAWT)

Development of vertical axis wind turbines has allowed several communities to install wind turbines in highly populated urban environments.

Traditionally, there are two distinct types of vertical axis wind turbines known by the names darrius and savonius, although hybrid versions also exist. Vertical axis wind turbines are more suited to urban areas as they are silent, have a reduced risk associated with their slower rates of rotation and can operate in low wind conditions. They usually consist of two or three curved blades of various shapes and sizes according to their application. The basic advantages of VAWTs are:

- Generator and gearbox are on the ground, avoiding the need for a tower and making maintenance easier;
- No need for a yaw mechanism to turn the rotor against the wind as the turbine receives wind from all directions;
- Only one axis of rotation which reduces vibration and stress on the turbine;
- Operates in low and high wind speed conditions with virtually no cutout speed, including turbulent and stormy conditions. Brisbane’s mean 9am wind speed is 7.4km/hr rising to a mean speed at 3pm of 12.6km/hr (Bureau of Meteorology, 2004).

The specific design and principle of operation make them very quiet. The main disadvantages are:

- Overall efficiency is much lower than the traditional HAWT;
- Expensive and not yet cost effective based on a per kilowatt capacity investment. (Energy for Sustainable Development, 2003).

Several systems are now commercially available including one that was recently installed in The Strand waterside development in Townsville, see Figure 6.16.

Figure 6.16 Installation of the Ropatec WRE.060 VAWT in Townsville

Source: (Townsville City Council, 2004)

The Townsville installation used an off the shelf product called the Ropatec WRE.060. The twin wind rotors are 4.5 metres high and sit on top of a 4 metre tower. The rotors are 3.3 metres wide and the whole system is designed to produce a maximum of 6kW of electrical energy. It is calculated to produce on average 16kWh per day or about enough electricity for an average Townsville dwelling (Townsville City Council, 2004).

This same system was considered for a housing development in Bradford, United Kingdom and although it was considered the best of the VAWT based systems on the market, it still had an estimated pay back period of 35 years. This was almost double the pay back period for the best performing HAWT based system, which had a pay back period of 20 years (Energy for Sustainable Development, 2003).

Smaller systems, such as Urban Turbines Neoga (Figure 6.17) are less dominating, but their efficiency also drops. The Neoga has an average annual output of 2000kWh compared to the Ropatec's 5,500kWh average and has an estimated payback period of 60 years (Energy for Sustainable Development, 2003).

Figure 6.17 Urban Turbines Neoga VAWT

Source: (Townsville City Council, 2004)

Such low energy output makes such systems, at this stage, uneconomic when compared to other forms of renewable energy generation such as PV cells.

6.6.2 Horizontal axis wind turbines (HAWT)

The most common form of wind generators, but traditionally not well suited to urban areas where there is increased wind turbulence and a lack of open space. Nevertheless, several systems have been installed around the world to demonstrate that such systems are feasible in an urban setting. Small-scale HAWT systems have also been considered for rooftop mounting, although careful planning is required to ensure that vibration is not transmitted into the building structure.

The housing development mentioned earlier in Bradford also considered HAWTs and indeed the final recommendation was for such a system to be installed. In this case, they chose a small to medium sized system that had a rated output of 6kW and an annual output of up to 20,000kWh, depending on the wind speeds available. The rotor diameter is 5.5 metres and it is installed on a 9 metre mast. The cost benefit analysis carried out gave a payback period of 20 years with an annual saving of £750 or approximately $1800 (Energy for Sustainable Development, 2003).

6.7 Other Applications

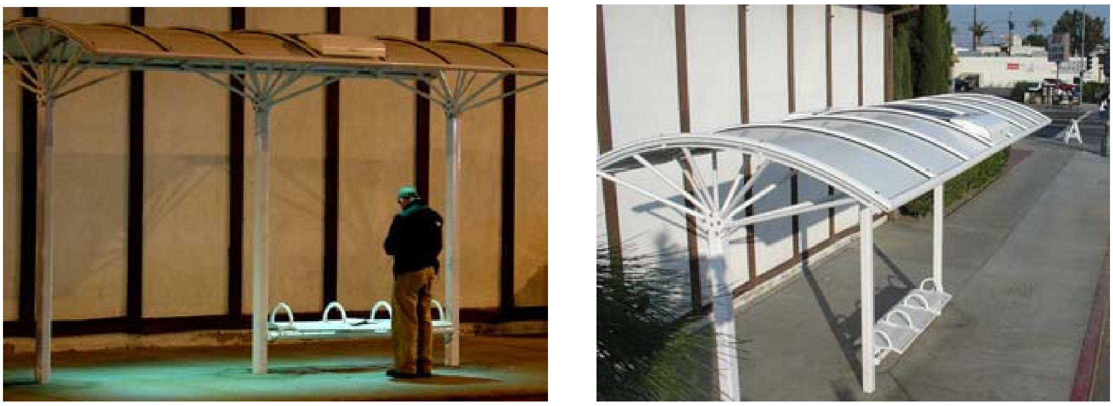
Most energy generating systems require specialist implementation into dwellings and communities. Often, systems will need to be developed and incorporated at the design stage of a building or sub-division to allow successful implementation. However, some "off-the-shelf" products are available that can be incorporated at any stage of a development or be part of a retrofit and upgrading program.

6.7.1 Solar Powered Bus Shelters

Carmanah Technologies have developed a solar-powered LED lighting kit for bus shelters that enables illuminated bus shelters to be installed with no external power requirements. The i-Shelter uses an integrated solar panel and battery pack, which powers durable, high-intensity light emitting diodes (LEDs), which have a life span of up to 100,000 hours, see Figure 6.18. As shelters do not require external power can be installed or upgraded without the typical disruption to footpaths and traffic patterns related to hardwiring (Carmanah

Technologies, 2004).

Figure 6.18 i-Shelter solar powered bus shelter



Source: (Carmanah Technologies, 2004)

6.7.2 Solar Lighting

Solar powered lighting systems are becoming more common in areas such as parks where grid connection is often difficult or expensive. Several systems exist; including an Australian developed system called 'Aussie Sunlight' by Sunlight Solar Systems, see Figure 6.19. Similar to the bus shelter, this system employs LED technology and is fully self-contained. The basic 6 hour system is guaranteed to give a minimum duty time of 6 hours operation in mid winter and 7.5 hours operation in summer in south-eastern Australia and in Brisbane this could be expected to be even longer (Sunlight Solar Systems, 2004).

The company also produces a grid connected solar lighting system called GreenStreets which generates energy during the day from its solar panels and injects this into the grid system. Energy from the grid is then drawn back at night. The generating capacity and the load are balanced so as to have a net zero effect over the year, see Figure 6.20.

Figure 6.19 Aussie Sunlight system

Figure 6.20 Grid connected solar lighting

Source: (Sunlight Solar Systems, 2004)

7. CONCLUSIONS

This scoping study set out to explore the relationship between sub-divisional layout and dwelling heating and cooling energy efficiency. The aim was to provide developers with the criteria for a tool to improve sub-divisional sustainability. In Phase one, the study examined the barriers that presently exist to improving sub-divisional sustainability as described by a range of key informants. Phase two examined a lot rating tool and used a new thermal software program to the impact of lot orientation, size and sub-divisional density on a range of case study dwelling types. The study also looked at the potential for sub-divisions to become energy efficient by supplementing reduced energy consumption with increased energy production.

This chapter consolidates the conclusions from the Studies and outlines the criteria for possible future tools that will enhance the capability to provide options for improving energy efficiency of dwellings in a sub-division at the rating stage. This Chapter also examines the next steps for this project.

7.1 Phase One Outcomes

Phase one of the study found that although the momentum towards energy efficiency is slow, it is multi-directional, encompassing elements such as energy and water. However, the industry representatives interviewed believe it is only a matter of time before momentum builds, and increased sustainable energy efficiency becomes the standard. To encourage this growth, several key areas need to be taken into consideration.

- Required and desired sustainability practices need to be clearly articulated and consistent to retain the competitive nature of industry. Other than BCA DTS provisions, there is no clear measure of how to achieve the necessary standard, or to meet increasing standards;
- There is a need for research to demonstrate that new and innovative models of sustainable development are more affordable than traditional models of development;
- There is a need for collaboration between local authorities, agencies, developers and consumers – to share a vision that is of benefit all parties;
- Where possible, incentives need to be introduced into the industry to make sustainable practices more attractive to the developers, suppliers and the homeowners, as well as emphasise the importance of the practice;
- Tools that measure energy efficiency need to be site specific, apply to the whole of industry, and take into account factors such as orientation, adjacent built forms, deciduous and evergreen vegetation, and a broad range of construction materials;
- Sustainable practices in development need to be recognised by the valuation and financial industry to overcome the financial barrier.

Regardless of these challenges, some developers are leading the way and demonstrating how sustainable suburbs can be incorporated into the current marketplace. Developments such as Sanctuary Pocket are acting as real world examples of what can be achieved and are providing the necessary driver that will enable large-scale adoption by the industry of sustainability practices in sub-division developments.

7.2 Phase Two Outcomes

7.2.1 Assessing and benchmarking energy efficiency

- The project found that the improved ventilation modelling resulted in a decrease of between 14 and 41 % in the annual total energy loads for the case study dwellings.

There is a marked variation in the range of annual total loads and this range suggests further design changes are required to optimise the energy efficiency of new dwellings.

- Research House and the Greensmart Home (case studies 1 and 2) were confirmed as benchmark dwellings. These dwellings address the range of sub-divisional issues developers face in SEQ, such as designing for increasingly steep slopes and for small sites, to reduce excessive solar access and optimise natural ventilation;
- This study quantifies the impact of dwelling orientation on energy efficiency. Using AccuRate, the orientation of the case study dwellings was altered at 45° increments throughout 360° and the annual total energy loads increased above the optimum by between 10 and 32 %. The variation in the annual total loads for the worst orientations (from 107.9 to 254.6 MJ/m²/annum) again highlights that further design changes are required to optimise the energy efficiency of new dwellings.

The main finding from this study is the impact on energy loads that result from increased suburban and urban densities. This study was triggered from within the project by the high percentage of small lots, coupled with key informants identifying increasing densities in Greenfield developments as an issue. The findings quantify and confirm common knowledge principles of the importance orientating for ventilation in SEQ:

- Using AccuRate, the case study dwellings were modelled at the presented orientations using two levels of external shielding and the annual total energy loads increased by between 5 and 15 %. The variation in annual total loads is of importance, ranging from 113.0 MJ/m²/annum (case study 1) to 259.4 MJ/m²/annum (case study 6). The impact of increasing the external shielding was either similar to, or exceed the impact of altering the orientation alone.
- The impact of increasing the external shielding either exceeded, or was similar in range and total to the impact of altering the orientation alone.
- Examining the combined impact of poor orientation and increased external shielding had to be restricted because of the number of simulations involved. However, in the case study examined, this combined impact created an increase of some 30 % in the annual total load.

Both the detached and attached dwellings recorded similar variations in total annual energy load in relation to altering the orientation and to increasing the shielding. However,

- The attached dwellings were between 7 to 50 % more efficient than similar sized detached dwellings.
- This level of comparative efficiency reduced as the number of conditioned spaces adjoining each apartment (alongside, above or below) lessened and the apartment came to function more as a separate dwelling.
- The range of cooling and annual total loads highlights the need for dwelling designers to have access to a tool that will allow them to augment passive design principles and test the energy efficiency of designs targeted for complex sites. This would enable them to test a variety of orientation, insulation and shading devices throughout the design development stage, rather than reacting to an inappropriate rating at a later stage.

7.2.2 Future tools for subdivisional layout

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 the assessment of buildings, there are no such tools or well-established methodologies for land development. This scoping study has found that there is a correlation between the efficiency of dwelling and the land that it is built upon and that lot related issues do play an important part in the overall efficiency that a dwelling is able to achieve. The challenge for land developers is to assess the likely impact that their subdivisional design will have on these future dwellings.

Assessment of existing lot rating methodologies has found that they only go part of the way in assessing the issues that need to be considered in SEQ. The current SEDA based methodology only assesses the impact of solar gain/protection, as this is probably the most important issue in the southern states. For SEQ the importance of ventilation, shielding and zero lot lines needs to be incorporated into any future tool.

In addition, it is important that such tools are easy and quick to use allowing users to quickly assess the impact of certain lot design options. Linking tools to existing GIS software is considered one of the best methods for achieving this.

7.2.3 On site energy generation

Moves towards energy efficiency within the dwelling have expanded to look at the possibilities of energy efficiency within a community. Australia's high use of fossil-based fuel for electricity production has resulted in becoming one of the world's highest contributors to greenhouse gases on a per capita basis. One way to reduce this impact is to look at ways to reduce energy consumption and to change the source of electricity generation.

Reducing energy consumption is by far the most practical and affordable way to reduce the impact. 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 implication. For Queensland, the single biggest consumer of energy in the house is hot water heating. The use of solar hot water systems can shift up to 90 % of this energy need from fossil fuel based sources to clean and free renewable energy sources. Although solar hot water systems do not actually produce electricity, the savings they make by shifting the energy need away from electricity are so significant that if all dwellings in Queensland were to adopt solar hot water heating the electricity savings would remove the need for additional power stations for many years.

Although energy efficiency and solar hot water systems can deliver enormous savings, the need for electricity is still growing and alternative decentralised sources are a real option. Photovoltaic cells, wind generators and co generation plants are all now viable options within community developments, although pay back periods can still be many years. Nevertheless, as the technology advances and uptake increases these payback periods can be expected to reduce, making such schemes much more attractive to developers of new communities.

7.3 Next Steps

This project was the first part in what is planned to be a series of scoping studies exploring a broad range of sustainability issues that are facing new subdivisions. The focus for this project was on energy efficiency and the link between dwelling energy efficiency and sub-divisional layout. Future projects are planned to investigate water sustainability and waste minimization.

7.3.1 Sustainable Sub-divisions: Energy

This scoping study has quantified the impact of orientation and shielding on energy efficiencies and developed criteria for a lot-rating tool for SEQ. In 2005, a proposal will be submitted for Sustainable Sub-divisions: Energy, Part 2.

7.3.2 Sustainable Sub-divisions: Water sustainability

There are a myriad of ways in which water supply, drainage and sanitation services can be provided to a residential dwelling and a lot in a Greenfield urban development. These range from the conventional approach of connecting to the centralised systems through to fully self-contained system within the lot, with many stages of decentralisation falling between these two ends of the spectrum.

The current method for designing and implementing an urban water system is driven by an initial decision about the scale (i.e. degree of centralisation or decentralisation) and style (e.g. conventional or non-conventional) of the service provision approach at the early stages of Greenfield development. Due to the long service life of housing stock and urban water system pipe assets, there is little opportunity to alter the scale and style of the water service over time, with retrofitting usually being a very expensive option. This is one of the factors that have produced the lock-in effect of the conventional approach to providing water supply, drainage and sanitation services in urban areas. It is inertia due to the long service life of the current pipe infrastructure as pipes have a lifetime of 50-100 years but other components have shorter service lives, such as treatment plants, pumps, and rainwater tanks etc., so water systems that have fewer pipes have least inertia.

There is also inertia amongst the stakeholders, due to the considerable caution about departing from conventional centralised systems; in part due to the difficultly in altering the water servicing systems once they are constructed. The water industry is in a period of considerable learning and change, with many new technologies emerging and the old arguments of economies of scale breaking down. However, there is still a large amount of flux in the industry and it will be some time before many of the questions about the economic, social and environmental dimensions of the myriad of ways in which water supply, drainage and sanitation services can be provided are answered.

The proposed Sustainable Subdivisions – Water project will investigate the concept of adaptability within residential dwellings in the subdivisional supply of water servicing. It will investigate new technologies that are emerging which can potentially replace what is currently available. The aim of the research is to determine if it is possible to design water-servicing flexibility into residential lots to provide the ability to vary onsite water systems from those fully reliant on the external system through to those fully self-contained. Flexibility would be investigated for all facets of the water cycle within various dwelling designs. In 2005, a proposal for Sustainable Sub-divisions: Water, will be submitted.

7.3.3 Sustainable Sub-divisions: Waste minimization

The residential construction industry produces a large amount of waste much of which can either be reduced or recycled. Presently, systems for on site waste collection and removal do not facilitate the recycling of waste as separation of materials is not undertaken, and so items that have the potential to be recycled are mixed with those that do not. In addition, the practice of undertaking the majority of the construction process on site also minimises the ability to recycle waste.

The Sustainable Subdivisions – Waste project would investigate the various waste streams that are generated during the construction of residential dwellings. It would look at ways of reducing these streams through schemes such as:

- On site waste separation;
- Off site waste separation;
- Development wide waste collection;
- Off site manufacturing;
- Prefabricated construction methods;
- Material recyclability;
- Reducing material use.

7.3.4 Other sustainability issues

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 (Bruntland Commission, 1987).*

Achieving this requires attention to nearly all aspects of current way of living, especially in countries like Australia where the current ecological footprint is far in excess of the world average, which itself is in excess of what the planet can actually support. Consequently, addressing all aspects of sustainability is a mammoth undertaking and attempting to deliver sustainable living without radical change may well be impossible. Nevertheless, projects such as this one and the planned future projects are all important steps on the way to achieving a sustainable future. Of course, 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, to name just a few. It is hoped that in the not too distant future these issues and others will be investigated more fully to assist in delivering subdivisions, suburbs and communities that are truly sustainable.

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Appendix B - Project Agreement

PROJECT INFORMATION:

Background

Australia's current pattern of urban development is unsustainable:

- Australia's per capita consumption of space (floor space, private open space, energy and water rank among the highest in the world and are continuing to increase.
- Australia's per capita waste streams also rank among the world's highest.
- Australia's metropolitan planning and development strategies deliver poor environmental outcomes in relation to:

    energy production and consumption and CO_2 (with rapid growth in transport vehicle kilometres travelled and closed mind to distributed energy/solar suburbs)

    stormwater and wastewater re-use e.g. for Sydney 640 GL of potable water is supplied, 550 GL of waste-water and 420 GL of stormwater is discharged.

An increasing number of governments (State, local) and private sector urban development companies are initiating major greenfield projects that aim to deliver enhanced environmental outcomes compared to a "business-as-usual" approach. Recent examples include: Sydney Olympic Village, Mawson Lakes in Adelaide, North Lakes in Brisbane and Victorian Urban Land Corporation's Epping North development in Melbourne.

This research is the first phase of a multi-stage Sustainable Sub-divisions project theme and thus focuses solely on energy performance of sub-divisions with a range of contemporary dwelling types such as:

- detached single storey – both slab-on-ground and elevated and pre-fabricated,
- detached double-storey,
- medium density multi-storey residential and mixed use, and
- small house – small office.
- high rise residential apartment

A new software tool for assessing ventilation in dwellings, particularly in sub-tropical climate zones, is currently being developed by CSIRO with the assistance of Federal government funds. There has been great demand for such a tool and determining its applicability to a whole sub-division with a range of development types beyond the typical single family house for which the original tools were developed, is emerging as an issue among design professionals and the development industry.

Business Basis

The market for information and tools which provide energy ratings and analysis of buildings is continuing to grow rapidly as owners, tenants and regulators seek more energy efficient products and product providers seek to create these products at the lowest cost. This project will contribute through:

- Providing information on a number of practical subdivisional aspects (eg. number, size and layout of dwellings) that have impact on energy efficiency;
- Developing criteria for possible future tools which will enhance the capability to provide options for improving energy efficiency of dwellings in a sub-division at the rating stage; and
- Addressing issue of appropriate housing energy performance standards for South East Queensland in context of materials, design and technology opportunities.

Project Statement

This is an investigative study which brings an integrated team together to identify the energy-efficiency demands of dwellings from a sub-division viewpoint as well as that from an individual dwelling. It will highlight challenges likely to fall mainly on the national housing industry with release of new energy codes and canvas the technologies available to housing for on-site electricity generation as a basis for development of solar suburbs. Industry responses will come from project sponsors and attendances at workshops focussing on the energy-efficiency of sub-division development.

The quantitative analysis of the energy-efficiency of dwellings and their relation to sub-division requirements will take advantage of new capabilities to assess appropriate ventilation in determining the energy performance of dwellings, particularly in sub-tropical climates.

The project methodology consists of: identifying sub-divisions on which will be built houses in four separate categories including; project homes, individual houses (one and two storey), medium density housing and SOHO (small office-home office). Plans will be obtained for an appropriate sample of dwellings in each category from which assessments and comparisons to the new and current energy efficiency standards in sub-tropical climate zones, will be undertaken. Interviewing and conducting a workshop with those who undertake sub-division planning, design and statutory compliance activities, and developing a set of criteria for possible future energy efficiency tools with priority weightings will also be undertaken.

The outcomes will include: workshop/interviews with sub-division developers, an appraisal of a new assessment tool which includes ventilation for house energy efficiency ratings, comparing this new tool against the current tool that is used for assessment, appraisal of the links between housing and sub-division in creating sustainable sub-divisions, and criteria for possible future tools for determining the performance and priorities of options for achieving energy efficient design in sub-divisions and dwellings.

The uniqueness of the project is in:

- Connection of “housing technology” to “sub-division technology” in sustainable sub-divisions.
- Access to a new assessment tool which includes a more appropriate ventilation model for rating energy-efficiency of dwellings.
- Advising industry on adequacy of current design options in context of an emerging energy code for residential buildings.

Research Methodology, Objectives, Strategies

This study will:

- Assess and benchmark the energy efficiency performance of proposed dwellings (including non-standard detached housing, project homes, medium density housing and SOHO) against national energy standards, as contained in the Building Code of Australia (BCA), at a number of sub-division sites using a new energy assessment and rating tool which better takes into account ventilation, particularly in sub-tropical areas as indicated by Zone 2 in Figure 1 below which shows the climate zones of Australia as defined by the current Building Code of Australia, Volume 2 (Amendment 12). The performance of this new rating tool will be compared against the current rating tool that is used in South East Queensland which is called BERS (Building Energy Rating System).

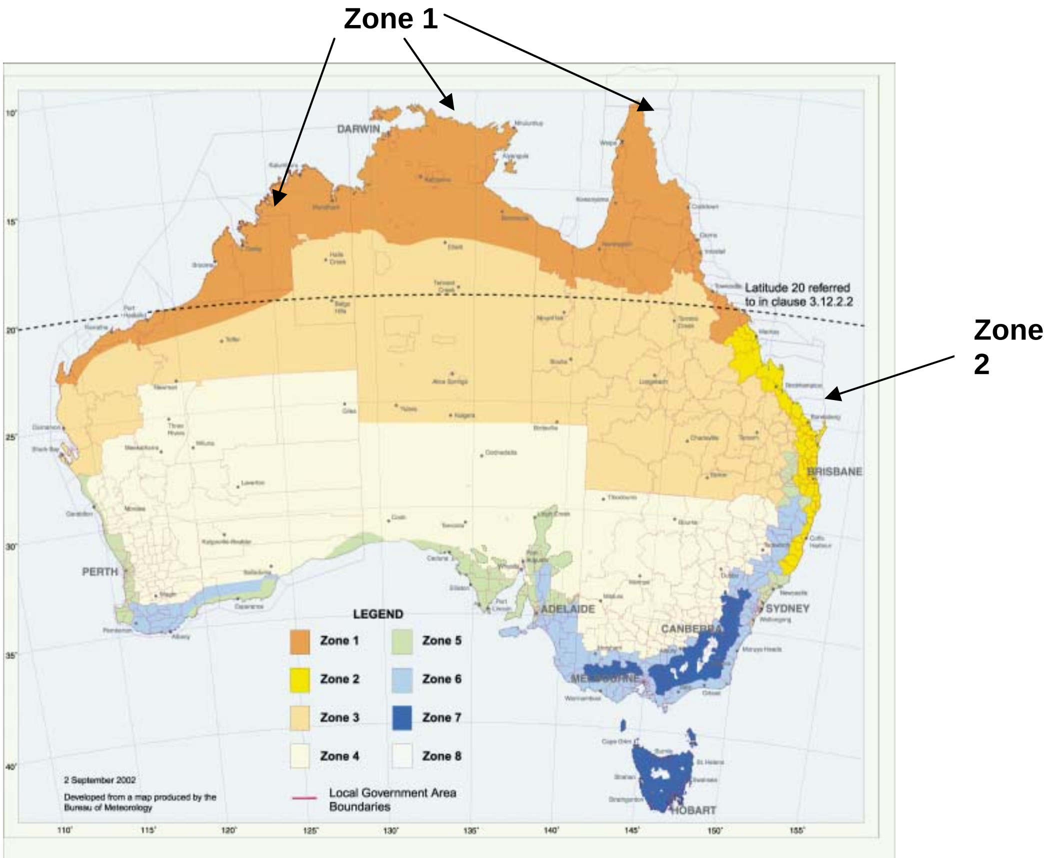


Figure 1

- Highlight challenges for the national housing industry with the release of new energy efficiency codes,
- Explore the technologies available to housing and sub-divisions for on-site electricity generation as a basis for the development of solar suburbs, including receptivity by electricity supply companies,
- Develop a set of criteria for possible future tools to prioritise options for improving house designs to bring their energy efficiency up to the desired standard,
- Investigate barriers to energy efficient innovation, primarily as a result of disconnection between "housing technology" and "sub-division technology".

The project methodology consists of the following activities:

- Identifying sub-divisions on which will be built houses in the four categories of project home, individual houses, prefabricated house, medium density house, SOHO and high rise residential.
- Obtaining plans for an appropriate sample of dwellings
- Interviewing industry professionals who undertake sub-division activities.

- Assessing the sample dwellings on the new and current standards
- Comparing the results for the different dwelling types in sub-tropical climate zones.
- Conducting one workshop with building industry professionals from the private and public sectors within South East Queensland on the requirements of sub-divisions and the performance of current assessment tools.
- Developing criteria for possible future energy efficiency tools.
- Writing a report.

The housing developments to be made available for study by CRC memBERS include:

- Kelvin Grove Medium density residential (Queensland Department of Public Works)
- Springfield residential (Springfield Land Corporation)
- Research House – Rockhampton (Queensland Department of Public Works)
- Pre fabricated house (Delfin Lend Lease)
- High rise apartment (to be determined)

Deliverables

Specific Project Deliverables:

Seven Deliverables are envisaged in this study:

- Workshop/interviews with sub-division developers (completed 3 months after project start)
- An appraisal of a new assessment tool for house energy efficiency ratings (completed by end of project); includes comparison of BERS with new NatHERS across all dwelling types.
- Brief appraisal of the national and/or international technologies available to housing and sub-divisions for on-site electricity generation as a basis for development of solar suburbs (completed by end of project)
- Set of criteria for possible future tools for determining the performance and priorities for achieving energy efficient design in sub-divisions and dwellings (completed by end of project), and
- A report on the barriers to energy efficient innovation, primarily as a result of disconnection between “housing technology” and “sub-division technology” (completed by end of project).
- Development of an indicative business/marketing plan to be utilised for the future activities in the Program B Sustainable Subdivisions projects.

CRC General Deliverables:

The CRC requires three levels of reporting outputs for each of its Projects – to maximise benefits to our participants:

- A comprehensive research report detailing the research background, literature reviews, objectives, methodology, data analysis and results, conclusions, implications, and recommendations for further research and commercialisation and dissemination opportunities.
- A 20 to 40-page industry-focused research summary suitable for dissemination as an industry-wide information booklet.
- A short summary brochure with executive summary style text and graphics of a maximum of four pages for promotional and marketing purposes.

The CRC also requires four levels of administrative reporting for each of the Projects to ensure the appropriate level of communication is able to occur between CRC participants:

- Informal and ongoing monthly reporting to the Development Manager. This reporting is to enable the Development Manager to compile a monthly internal report.
- Quarterly Progress Reports, reporting on research, technical and project management progress for Research Committee and Board presentations.
- Project Reviews, every six months or as determined by the CRC.
- Active and timely participation and provision of information for media releases, participants' promotional and educational outlets as determined by CRC.

Reporting and Dissemination:

- Provide monthly and quarterly progress reporting and participate in project reviews as determined by CRC.
- Three workshops between industry and research participants.
- Minimum three (two national and one international) refereed publications.
- Active participation and provision of information for media releases, participants' promotional and educational outlets as determined by CRC.

Key Assumptions

The key assumption is that there is an expanding market for information on energy efficient building practices and products. As new energy efficiency regulations are developed this need will grow even more and create a significant demand for information on available assessment tools (for rating energy efficient designs), sub-division issues (orientation, solar access, etc.), products for delivering energy efficiency (solar technology, glazing systems, insulation, etc.) and low energy building products and materials.

Background Intellectual Property

From Project Participants:

There is a certain amount of background IP linked to CRC partners. CSIRO will make available the updated NatHERS software which will be used in the assessment of dwellings in accordance to the BIP provisions of the CRC Centre Agreement. NatHERS is the Nationwide House Energy Rating Scheme and is owned by CSIRO. The updated version of the program has improved ventilation modelling specifically designed to deal with sub-tropical climate conditions. At present, NatHERS is the main software tool endorsed by the ABCB for rating houses. CSIRO also has a licence for the BERS software which will be used for comparison purposes against the NatHERS software. The use of BERS software on this project is subject to CSIRO confirming the license allows such an activity.

Acquired from Other Sources

N/A

Project Participants Rights

N/A

Commercialisation/Implementation/Education and Training/Technology Diffusion

The market for information and tools which provide energy ratings and analysis of buildings is continuing to grow rapidly as the ultimate consumers, the owners and tenants, seek more energy efficient products and the providers seek to create such products at the lowest cost. This project will contribute through:

- Workshop on practical aspects of energy efficient sub-divisions
- "Road testing" a new energy rating tool that specifically includes ventilation modelling and comparing it against current rating tools,
- Comparing efficiencies of different sub-division and dwelling types, and
- The development of criteria for possible future energy efficiency assessment tools with consideration to their applicability to a range of sub-division and dwelling types as well as providing cost effective options for reaching required building standards. This would satisfy a demand, which so far, has remained unfulfilled.

This is an investigative study, which will include establishing criteria for potential energy efficiency tools and their possible markets. A marketing strategy will be created as part of the workshops/interviews undertaken during the project. The criteria established are seen as the intellectual property created through this project and would deliver a possible benchmark for future energy efficiency tools.

Summary of Potential Opportunities and Problems

Potential Opportunities

- The updated NatHERS software to be used is new and not yet publicly available, but is likely to be designated as the national tool of choice for dwelling energy assessment by the appropriate authorities.
- An increasing percentage of new dwellings are in the climate zones being focussed on (Zone 2 in Figure 1). Latest data from the Australian Bureau of Statistics shows that in Queensland the number of dwelling units approved in the 2002 calendar year increased by 30.0 % compared with 2001. Other dwellings rose by 50.5 % while houses rose by 21.9 %. For the same period total dwelling units approved in Australia fell 3.1 %, with houses falling by 11.2 %. This shows the dramatic difference in housing trends in Queensland and how it is defying the national downward trend in approvals

Potential Problems

The critical success factors are:

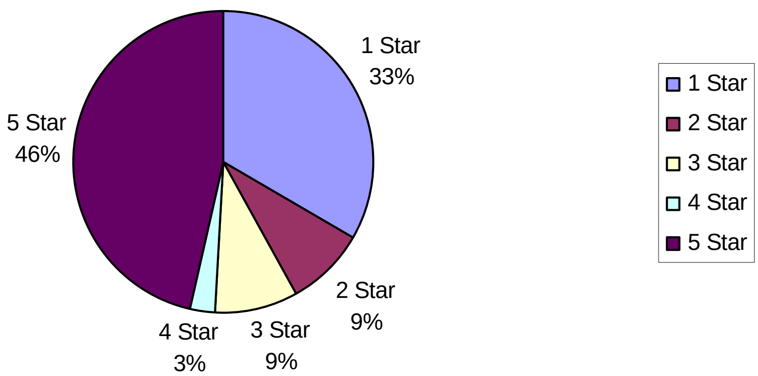
- Accessibility to sub-division and dwelling plans from participants, without which no quantitative assessments can be undertaken. The developers participating in the project have agreed to initial approval.
- Availability of a new NatHERS energy efficiency rating software which is required for assessment of energy efficiency of dwellings and ventilation modelling. This software has been completed in May 2003.

Appendix C - Lot Rating Case Studies

C.1 Case study sub-division 1

Figure 8.1 Case study 1 - lots 856 to 945, The Summit, Springfield

Figure 8.2 Case study 1 – lot ratings



C.2 Case study sub-division 2

Figure 8.3 Case study 2 lots 1095 to 1141, The Vista, Brookwater

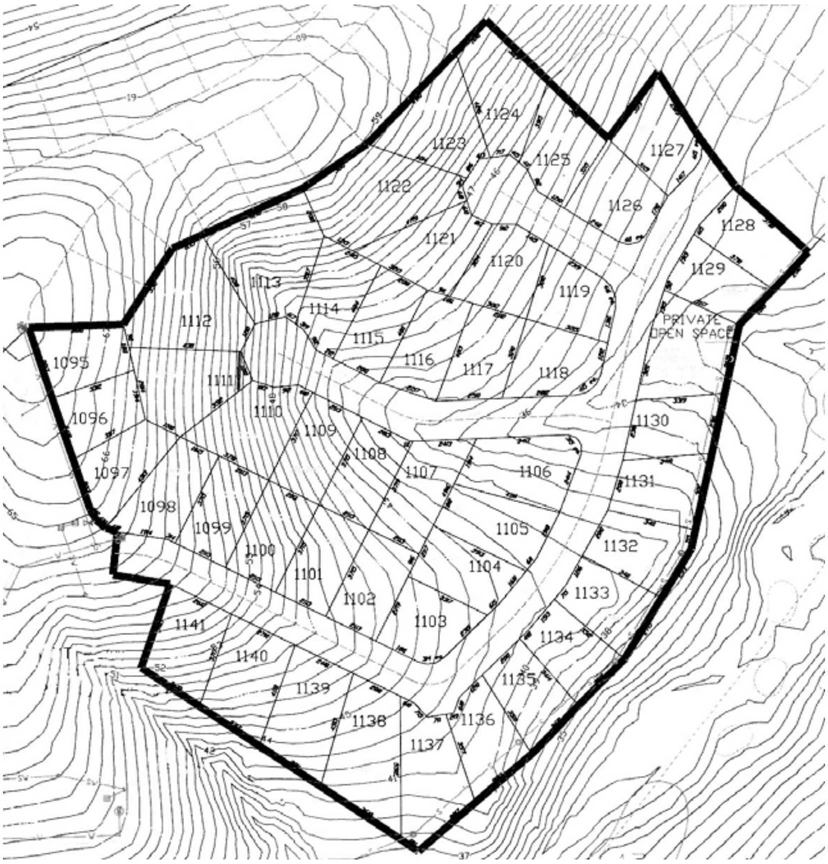
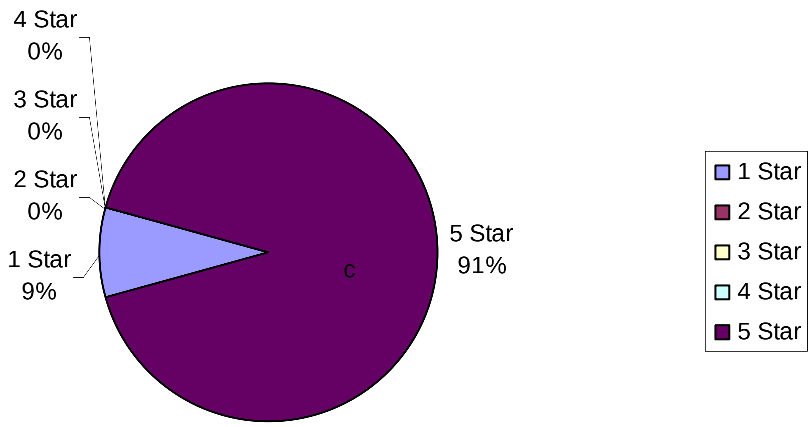


Figure 8.4 Case study 1 – lot ratings



C.3 Case study sub-division 3

Figure 8.5 Case study 3, lots 2194 to 2229, The Ridge, Brookwater

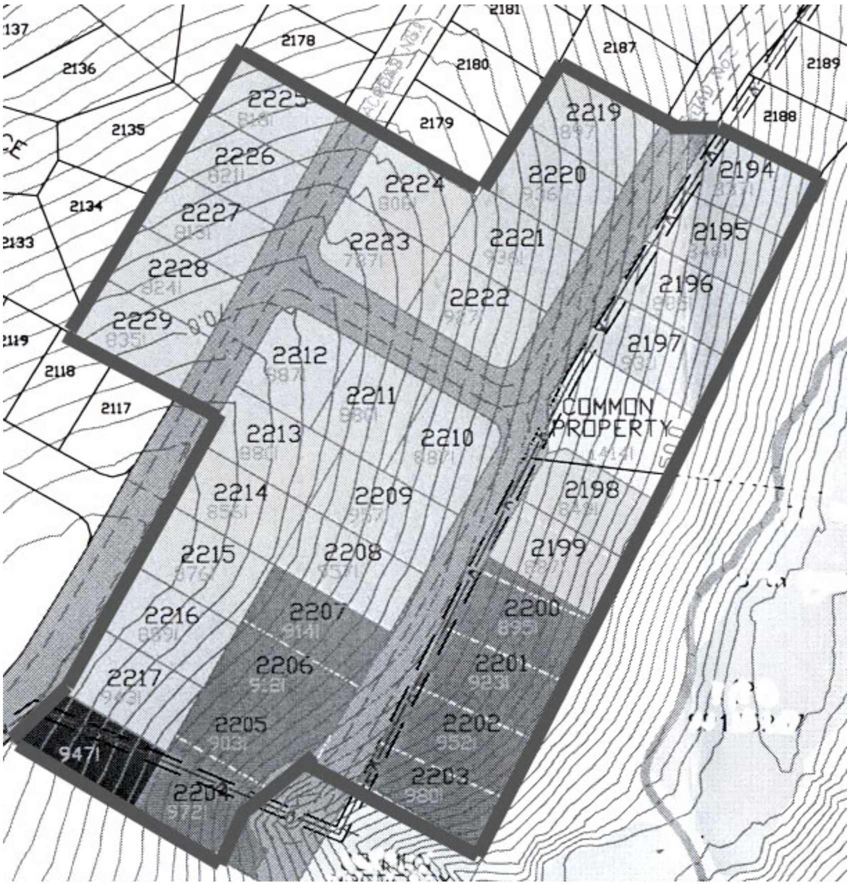
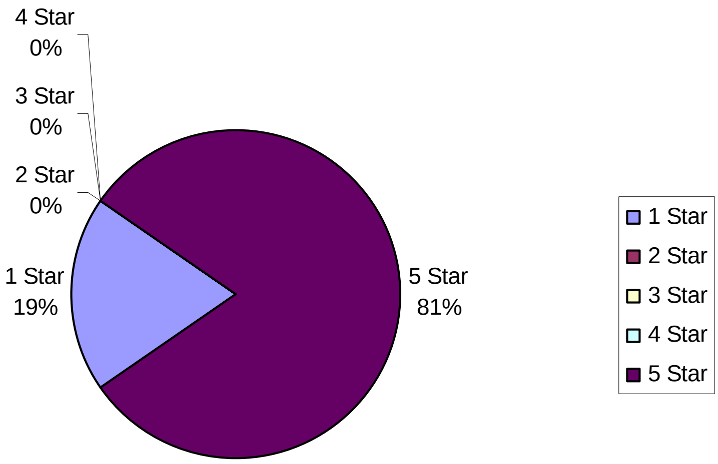


Figure 8.6 Case study 3 – lot ratings



C.4 Case study sub-division 4

Figure 8.7 Case study 4, lots 3001 to 3069, The Panorama, Brookwater

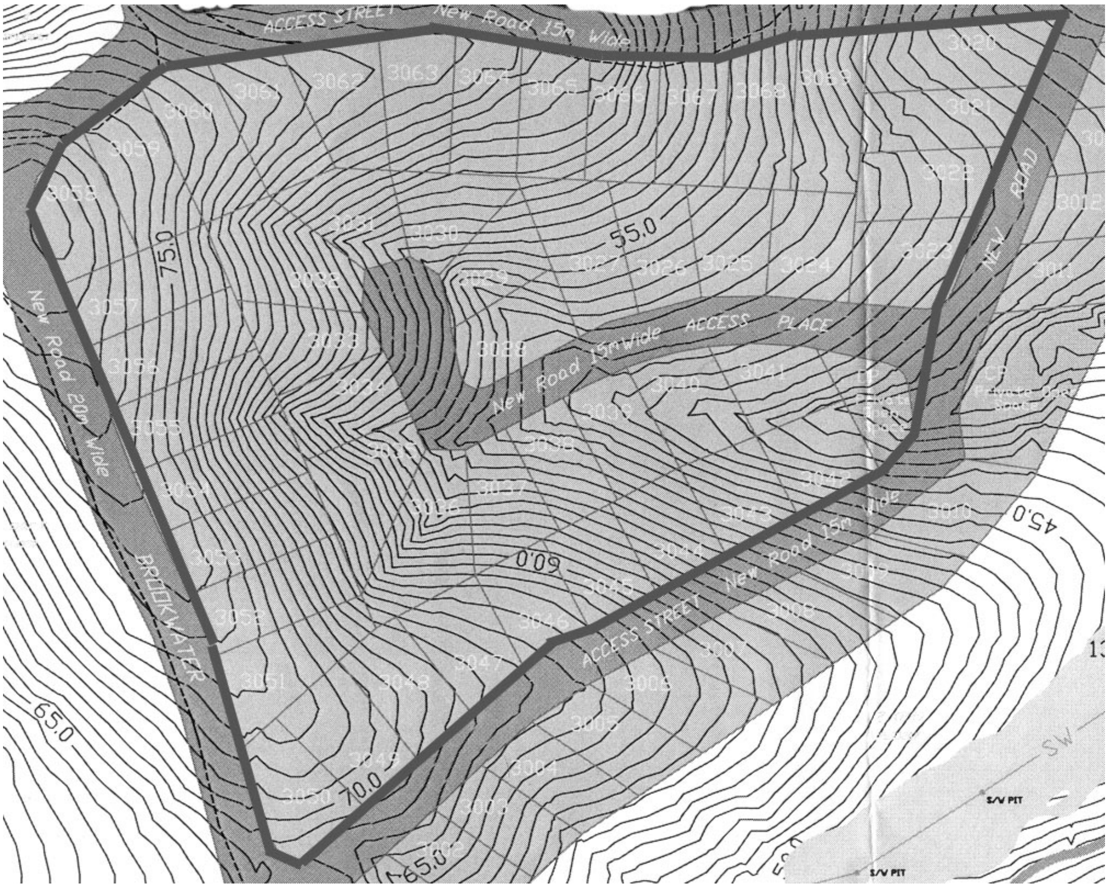
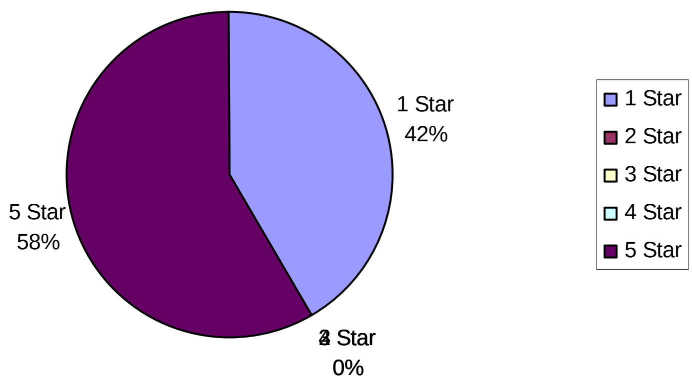


Figure 8.8 Case study 4 – lot ratings



Appendix D - Dwelling Case Studies

D.1 Introduction

The aim of this section is to

- Introduce the format and terms used throughout the case study presentations;
- Introduce the thermal simulation programs used to examine the case studies – specifically BERS V3.2 and AccuRate V0.99; and to
- Present the case studies.

D.2 Selection of Case Study Dwellings

The objective of these case studies is to provide a snapshot of the EER of a range of dwellings types that commonly occur in new developments in SEQ. The case study dwellings were intended to represent a range of contemporary dwelling types, rather than focusing on specific dwellings. These types fall into two broad categories, detached and attached, and include:

- Detached single storey – slab on ground, elevated and pre-fabricated;
- Detached double storey and split level;
- Attached medium density multi-storey residential (2 or 3 level, walk up); and
- Attached high-density multi-storey residential (over 4 storeys).

A fifth category, small house – small office (SOHO) was originally identified, but throughout the course of the study it became apparent that it was not practicable to separate what is essentially a small space within a dwelling, into a discrete category. Instead, this use has been identified and included in the thermal modelling for some of the following case studies.

The case study selection was limited to plans that could be provided by Project Partners. The Project Brief delineated SEQ as the study area, but in some instances the plans provided referred to dwellings located outside the case study area. To retain the appropriate focus and to eliminate variations based on differing climatic conditions, all detached dwellings are modelled as if located at Springfield (Climate Zone 9). The medium and high-density dwellings are modelled as if located in the Kelvin Grove Urban Village (KGUV) (Climate Zone 10). This will result in the case studies being modelled with different climatic settings, but that reflects the reality of new developments in SEQ where Greenfield developments are occurring further and further away from both the CBD and the coastal areas.

D.2.1 Presentation of the case study dwellings

Each of the case study presentations will include a site plan, floor plans and elevations, where these have been provided. The images have been proportionally reduced to suit page layout and are not to scale. Dimensions have not been included.

In Phase One, the key informants commonly described both the lots and dwellings according to size with a small lot being defined as less than 450m^2, or less than 15 metres wide, and large lots as over 560m^2. A small dwelling was less than 200m^2 internal floor space, which may include a garage, but excludes balconies, pergolas and the like.

D.2.2 Thermal Program comparisons

Phase Two of the project analysed samples of various dwellings constructed on different size lots by comparing the energy loads achieved in the current rating tools, NatHERS (Nationwide Housing Energy Rating Scheme) and, where appropriate, BERS (Building Energy Rating System). This phase also involved using a new electronic energy assessment rating tool, AccuRate, which takes into account not only the physical built form, but specific site elements, such as orientation and access to natural breezes.

In the development version of AccuRate, it was possible to run a simulation using the NatHERS ventilation model instead of AccuRate's own ventilation model. The NatHERS ventilation model makes some provision for ventilation, but is far less detailed than AccuRate's ventilation model. This 'NatHERS simple ventilation' modelling provides a benchmark for comparison with BERS and AccuRate, which progressively improve the ventilation modelling.

In some instances, an external assessor, using either BERS or FirstRate, had already modelled the dwellings. The ratings data was made available for this study, but the data files were not provided. As a result, further examination of these dwellings, such as increasing the external shielding or altering the orientation, was not possible.

BERS was designed to test the annual thermal performance of Class 1 dwellings only and consequently BERS was not used to examine the Class 2 dwellings and the program comparisons for the Class 2 dwellings are between NatHERS and AccuRate.

D.2.3 Star rating 'to be confirmed'

The present Star Band settings cover a range of 1-5 stars with 5 being the highest and optimum level.

The star band settings are derived from the annual total energy load as follows;

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

One of the aims of AccuRate is to remove the 'bias' toward large houses that exists in all current thermal programs. At present, this floor area basis of rating makes it easier for a large house to get a higher rating than a small house. Corrections commissioned by the AGO will be incorporated into AccuRate;

- Dwellings with an internal floor area below 200 m^2, have the MJ/m^2 adjusted downward;
- Dwellings with an internal floor area above 200 m^2 have the MJ/m^2 adjusted upward.This correction will be applied after the energy loads have been calculated and will appear on the ratings report as the Area Adjusted Star Band Score, as shown in the following sample report. This Score will determine the final star rating of the dwelling, using Band Width data supplied by the Australian Greenhouse Office (AGO).

At present, there are calibration issues still to be resolved with the Area Adjusted Band Score Thresholds. As a result, this study will discuss the dwelling ratings in terms of MJ/m^2/annum and not in terms of star ratings, which will be noted as 'to be confirmed' (TBC).

The absence of the area adjusted star ratings makes it difficult to determine what constitutes a significant variation. A significant variation in annual total load could be considered as a variation that causes the star band score to alter by ±½ Star. This has added an unexpected degree of difficulty in interpreting the data and has led to the need to include more detail in each case study in place of a 1-5 star indicator. The point of comparison then must lie within the simulations run for each dwelling and in the totals between the case studies.

D.2.4 Constructions assumptions

In order for the EER assessments to be carried out on the case study dwellings, it was necessary for a number of assumptions to be made about the dwelling construction and operation. Some of these construction assumptions are built into the software and vary between the two programs used. Other assumptions arose because the level of data required for the program simulations was not discernable from the plans supplied and time precluded individual discussions with the designers to clarify exact construction details. An example of this is the colour of the external and internal surfaces, which is rarely noted on plans, but impacts on thermal performance. In the absence of this information, medium colours have been assumed for all surfaces in all case study dwellings.

The following paragraphs detail the general constructions assumptions adopted for this study. Throughout the case studies, the construction of the dwellings will be discussed where they fall outside the selections currently offered in the thermal programs. This will enable the possible impact of these constructions on the modelling results to be considered.

Roof and ceiling insulation

For Class 1 buildings, the ceiling insulation was assumed to conform to the minimum total added R-value for different roof and ceiling constructions type as set out in the BCA. That is, it was assumed that the roof would be sarked and the ceiling would have R2.5 bulk insulation. The phrase R-Value means the thermal resistance ($m^2.K/W$) of a component calculated by dividing its thickness by its thermal conductivity. The total R-Value means the sum of the R-Values of the individual component layers in a composite element including the air space and associated surface resistances.

Roof spaces can be ventilated by a variety of means such as soffit vents, operable gables, spinning air vents and the like. AccuRate allows a selection of either 'standard' or 'ventilated', with ventilated indicating that purpose-built ventilation openings are provided. Detail on roof space ventilation was only provided for case studies 1 and 2, Research House and the Greensmart Home, and 'ventilated' was selected in these instances. The remaining case studies were modelled with 'standard' roof space ventilation.

It was assumed that the Class 2 dwellings would have ceiling insulation in the top floor only.

External walls

For Class 1 buildings, the wall insulation minimum added R-value for each external wall construction type is set out in the BCA. In Queensland, the added R value to create a composite R1 wall ranges from R0.46 to R0.60 (ABCB, 2004). The total R-value achieved for each dwelling depends on the combination of materials selected and this information was not available for this project.

In BERS, the R-value of the insulation can be entered and R0.5 was assumed for each wall type.

The AccuRate library offers an extensive list of insulation types and for reflective insulation and refers to the emissivity value of each product. The lower the emissivity, the more effective the insulating barrier is in reflecting heat away from the dwelling.

It was assumed that the Class 2 dwellings would have uninsulated external walls.

Fans

The inclusion of fans in a thermal modelling tool is a subject of some debate with opinions varying over whether fans are an appliance that seeks to address shortcomings in the dwelling design, or whether they are a designed for part of the performance of the overall dwelling.

Fans are included in the BERS program, but not in AccuRate, as the intention of that program is to test the performance of the building envelope. For this project however, very few electrical or reflected ceiling plans were provided and so the presence or absence of items such as fans or exhaust fans could not generally be determined.

Floors

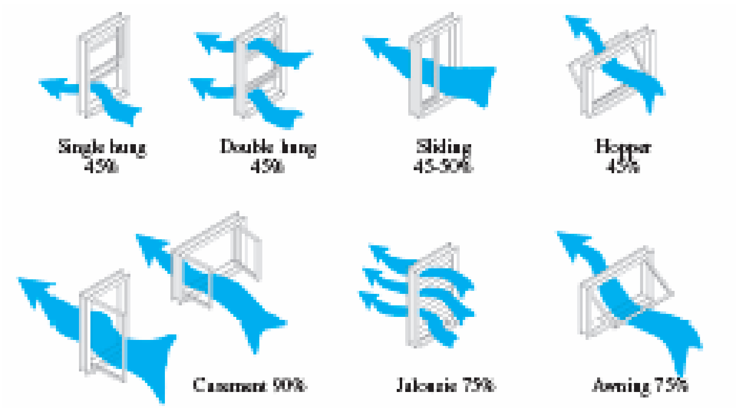
The BCA does not require floor insulation in Queensland and insulation has only been added where indicated on the plans provided. The flooring constructions are noted throughout the case studies. The floor coverings were generally assumed to be carpet throughout with ceramic tiles in kitchen, bathroom and laundry areas. Garage floors are assumed to be bare concrete slabs.

Windows

The window frames were assumed to be standard aluminium throughout. In BERS the window type selection refers to the framing material and to the thickness of the glass, but not to the opening style, which determines the openable percentage. It is not known how BERS calculates the percentage of ventilation for each window.

AccuRate also offers a range of framing materials and glass thicknesses, but also requires that the openable percentage of the windows be entered. It could be helpful to standardize the selection of either window types, or openable percentages to restrict ventilation assumptions. For this project, the openable percentages were assumed to be as follows:

Figure 8.9 Effective Opening percentages for various window types



Source: (DBEDT, 2001)

Both programs offer a range of window coverings, but this data is rarely available on the plans. Window coverings were assumed to be Holland blinds throughout. Medium colours were assumed for all external and internal surfaces throughout.

D.2.5 Zoning regimes

A zone is a space or group of spaces that are expected to be at a uniform temperature. The purpose of dividing the floor plan into zones is to allow different heating and cooling regimes, (or comfort conditions) for living, sleeping and service areas (Solar Logic, 2000). The heating and cooling requirements are calculated hourly over a period of one year, using real weather data appropriate for the location.

Determining the zone layout is a matter of judgement. For example, two adjacent bedrooms that each have one window in the south façade might reasonably be combined into one zone, but if one bedroom has a west facing window and the other a south facing window, there is a case for separating them into different zones because of the likely differences in solar heat gains (Delsante, 2004).

In both programs, each zone is classified as being of a certain type. The zone type determines certain modelling and other assumptions as described below.

In BERS V3.2, there are two zones available for each of the three types:

Zone type	Assumptions	
Living	2 available	Both will be heated and cooled (conditioned)
Sleeping	2 available	Both can be conditioned. However if 2 living areas have been selected, then only one sleeping space will be conditioned
Service	2 available	Neither will be conditioned

In AccuRate V0.99, the maximum number of zones allowed by the simulation engine is 99.

Generally, accuracy increases as the number of zones increases, but so does the running time. For the current version of the software, it is recommended that no more than 20 zones be created. A description of the AccuRate zone types and assumptions follows:

Zone type	Assumptions
Living/kitchen	Occupied during the waking hours (0700-2400).
	Cooking heat gains included
	This zone is conditioned
Living	Occupied during the waking hours (0700-2400)
	No cooking heat gains
	This zone is conditioned
	This zone acquires heat gains, approximate to several people and equipment such as televisions. It is recommended that only one, or at most two, zones that are occupied during the day be classified as type 'Living'. Other such zones are better classified as type 'Other'.
Bedroom	Occupied during the sleeping hours (2400 - 0700)
	This zone is conditioned
Other	Occupied during the waking hours (0700-2400)
	No occupancy heat gains
	This zone is not conditioned.
Roof Space	Invokes special roofspace model
	Do not use this type for habitable spaces, e.g. attic rooms
Sub-floor	Invokes special sub-floor space model
	Do not use this type for habitable spaces, e.g. basement rooms

User behaviour

The user behaviour assumptions outlined above are built into the software and cannot be varied for rating purposes. These behaviours do not necessarily reflect common household patterns and also make no allowance for differences between weekday and weekend use. As the performance of the building envelope is being assessed, there is also no allowance for lighting and appliance use (Energy Efficient Strategies, 2002).

Conditioned floor space comparisons

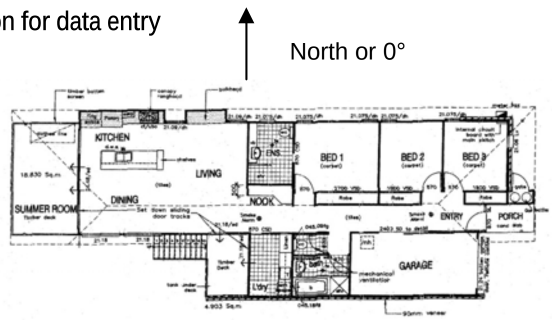
The aim of comparing the floor areas is to determine the variations in conditioned floor areas that result from the zoning characteristics and from the different data entry methods. These differences affect the thermal performance of the dwelling. The focus was on establishing the percentage of conditioned floor area to allow the impact of these variations to be considered. No attempt was made to ensure that the percentage of conditioned floor area was similar in both programs. The conditioned floor area for the dwelling appears on the EER assessment statement.

D.2.6 Impact of orientation on energy efficiency

The Lot Rating Tool Study is assessing the appropriateness of the lot-rating tool developed by the Sustainable Energy Development Authority (SEDA) for SEQ. To inform this Study, both the detached and attached dwellings were modelled at 45° increments throughout 360° to assess the impact of orientation on the energy load.

The default orientation for the plans in both programs is with geographic north facing vertically up the page. Data is typically entered as the plan is presented on the page – that is as if the walls to the top of the page are taken as north facing, or 0° and then clockwise from that point.

Figure 8.10 Default orientation for data entry



The orientation is adjusted after all external walls and roofs have been entered and checked, especially with respect to their azimuths. In the case studies, the default orientation is noted and is the starting point for the orientation simulations. The resultant range of EERs will inform the development of a set of criteria for future sub tropical sub-divisional layouts.

It should be noted that it was not part of this project to assess the appropriateness of the design to the site as presented, or to offer alternative design options.

D.2.7 Impact of increased external shielding on energy efficiency

The Project Brief focused on examining orientation; but the need to include shielding simulations was triggered by the following issues;

- The Phase One key informants identification of increasing densities in Greenfield developments; coupled with
- Consideration of the high percentage of small lots in lot rating case study 1.

In BERS, the ventilation selection, terrain type and the wind speed data from the climate file, determines the number of air changes per hour that are possible when the windows, doors and other adjustable vents are opened. The ventilation selection relates to the cross ventilation potential for cooling in hot weather and the ‘terrain type’ determines the attenuation of the wind about the building. This may be due to other buildings and obstacles as well as land forms which cause wind shadows or funnel the wind towards the building.

The BERS assessor can select from the following terrain types:

- Exposed;
- Open;
- Suburban;
- Protected.

In AccuRate, the position of each external opening is entered and the program calculates the internal cross ventilation capacity. The external shielding selection follows:

- 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-city housing.

In a suburban setting, increased densities, zero lot coverage, high, solid fencing, close and dense foliage or high retaining walls all combine to reduce natural ventilation. Modelling the impact of increasing external shielding is the ‘flip side’ of developing a more sophisticated software package that allows for increased ventilation.

Determining the shielding is a matter of judgement based on the assessors’ knowledge of local conditions, as detailed information is rarely available at the time of assessment. This portion of the study is outside the original intent of the project and so the number of additional simulations, such as examining the combined impact of a combination of increased shielding and altering the orientation, had to be limited.

D.3 Case Studies 1 to 15 - Detached Dwellings

For the purpose of this study, the term ‘individual dwelling’ is used to describe dwellings that have been designed to include a range of sustainable and safety features for demonstration, education and/or research purposes. Recent dwellings include Research House, Rockhampton and the Greensmart Homes at Springfield.

D.3.1 Case study 1 – individual dwelling (Research House)

Research House, Rockhampton is a research and demonstration dwelling that is expected to set the benchmark for sub-tropical dwellings. For the purposes of this study, all detached dwellings, including this one, have been modelled as if located in the same climatic zone at Springfield.

Figure 8.11 Site plan

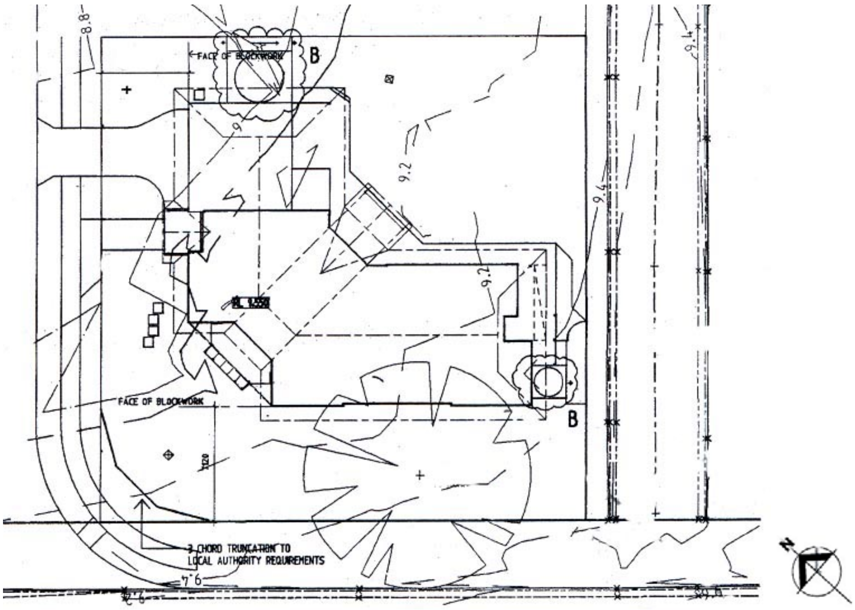
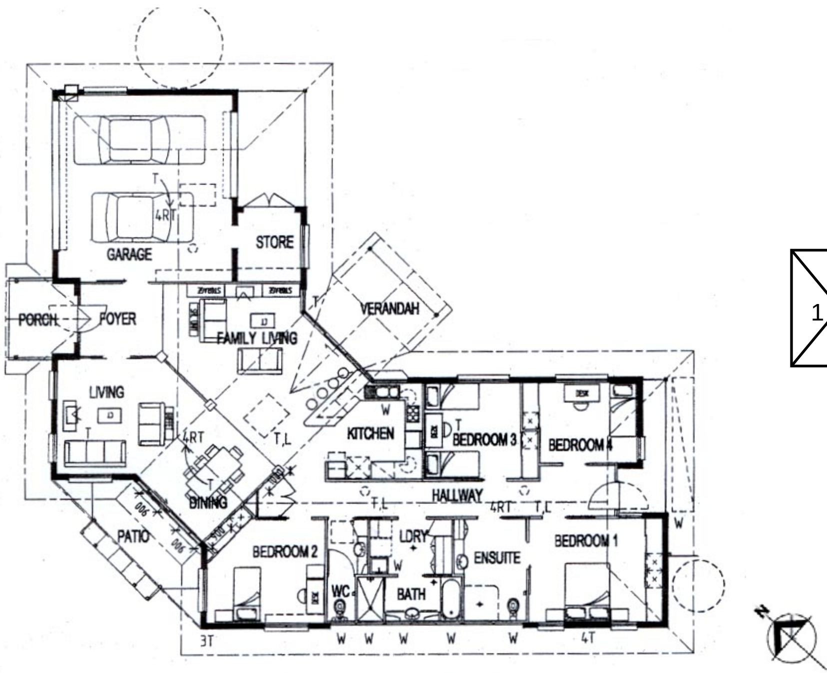
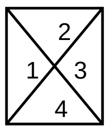


Figure 8.12 Floor plan





- Single storey, flyash veneer on slab, metal roof
- Large (220m² internal space) 4 bedroom (or 3 bedroom + SOHO), 2 pedestal.

Figure 8.13 Elevation 1 – north west

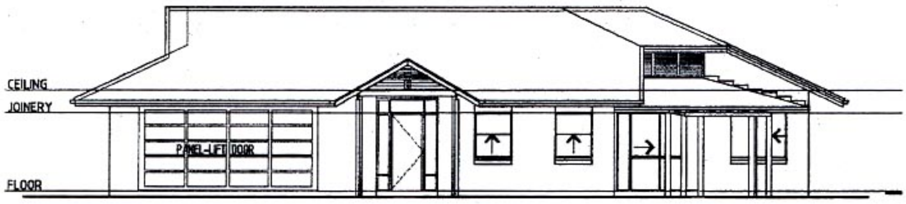


Figure 8.14 Elevation 2 – north east

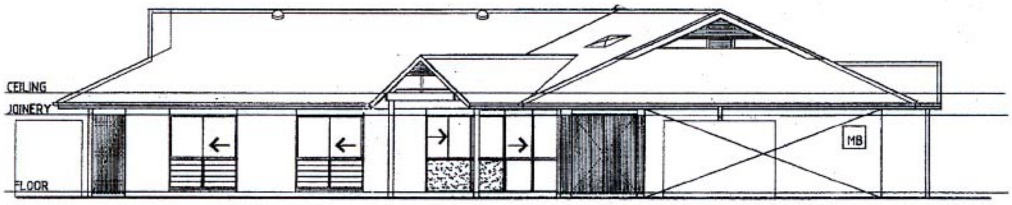


Figure 8.15 Elevation 3 – south east

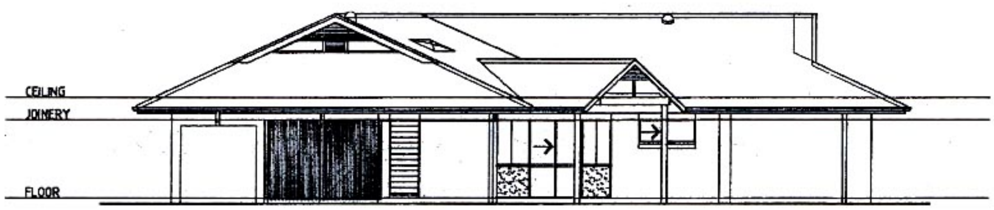
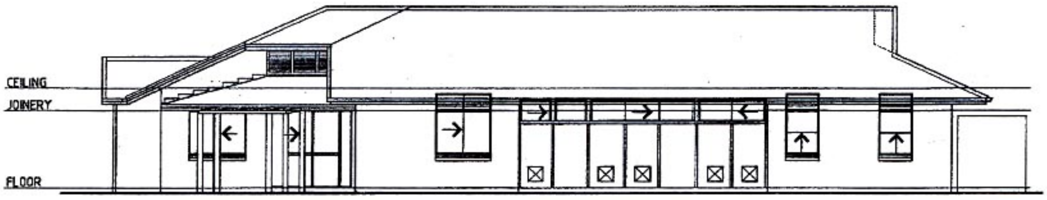


Figure 8.16 Elevation 4 – south west



Constructions

External Walls

- The external walls are concrete core-filled fly ash blocks (clay bricks standard building practice) channel & 10 mm foil backed plasterboard.
- This construction material is not currently available in either program. For the purposes of this study, the AccuRate simulation selection was AAC 200mm block. This selection was based on the following data 'Central Queensland University tested the fly ash blocks for thermal conductivity which was found to be '0.73W/mk (+/- 0.03)'. The compressive strength test results provided by Abigroup were 17.7 MPA. This compares favourably to the Building Code of Australia (BCA), which mandates a compressive strength of 15MPA for domestic block construction in Queensland. Dr Steven Szokolay calculated the thermal resistance (R value) of the fly ash blocks to be 0.86 using data from the thermal conductivity test conducted by the Central Queensland University (CQU)' (DPW, 2004).

Curtains and colours

- External and internal colours and window covering selections must be made in both programs, but this data is rarely available at the time of assessment.
- For the purposes of this study, all dwellings were modelled with medium colours for external and internal surfaces and Holland blinds were selected for all window coverings.

Roof

- For roof ventilation, the choice is either 'Standard' and 'Ventilated'. Ventilated indicates that purpose-built ventilation openings are provided and was selected for this study.
- However, the case study roof has a number of ventilation grilles, which may provide significantly more ventilation than that allowed in AccuRate.

Ceiling

- Material is 10mm superceil plasterboard, which is high strength plasterboard.
- The simulation selection was standard plasterboard 13mm with R2.5 bulk insulation

Internal Walls

- Metal foil laminated onto plasterboard
- Simulation selection - plasterboard with unventilated reflective airgap selected.

Skylights

- Skylight with shaft selected (single glazed clear normal & tubular).

Windows

- *S*tandard 3mm glass.
- Simulation selection 4mm clear glass. One window is 6mm laminated solar control glazing. This was ignored for simulation purposes.

Metal louvers

- Metal louvers are not available in either program and so glass was selected. This is not expected to impact significantly on the thermal performance, as these louvers are shaded.

Fans

- Expected to have been included in the BERS assessment.
- Not included in AccuRate modelling, which tests the performance of the building envelope.

Ventilation - insect screens

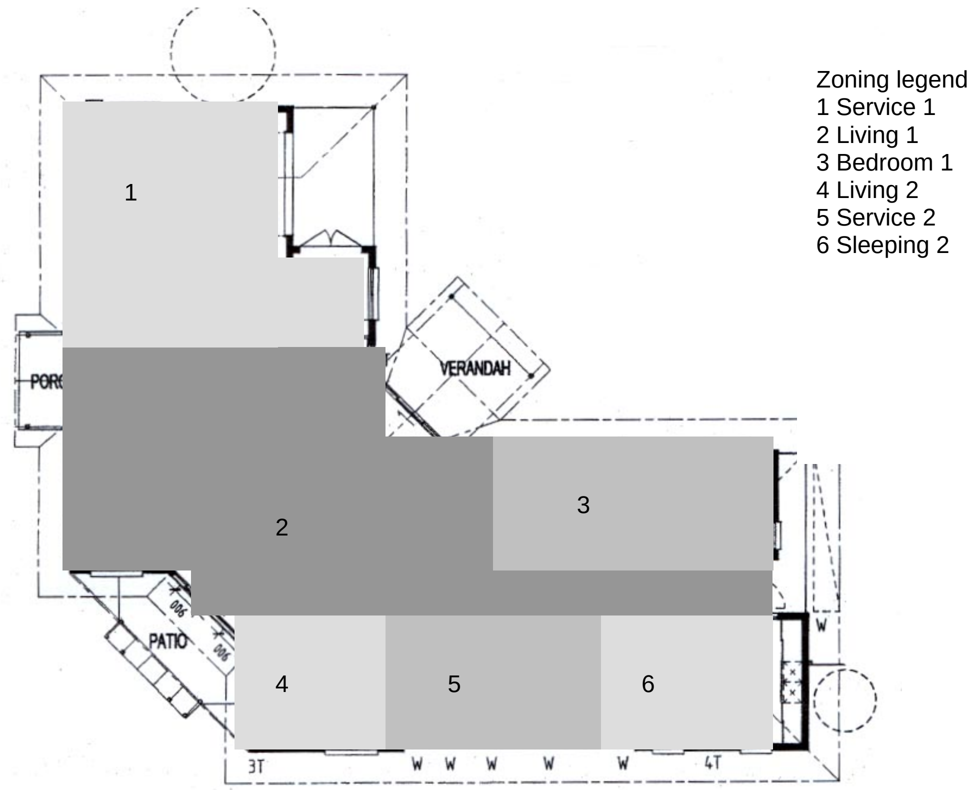
- The Crimsafe security screens installed throughout may have a heavier air flow reduction factor than normal insect screens.
- Simulation selection – insect screens checked.

Impact of zoning regimes on assessing energy efficiency

At the design stage, Project Services, a commercial business unit of DPW, undertook a BERS evaluation of Research House and determined a 5 star rating (DPW, 2004).

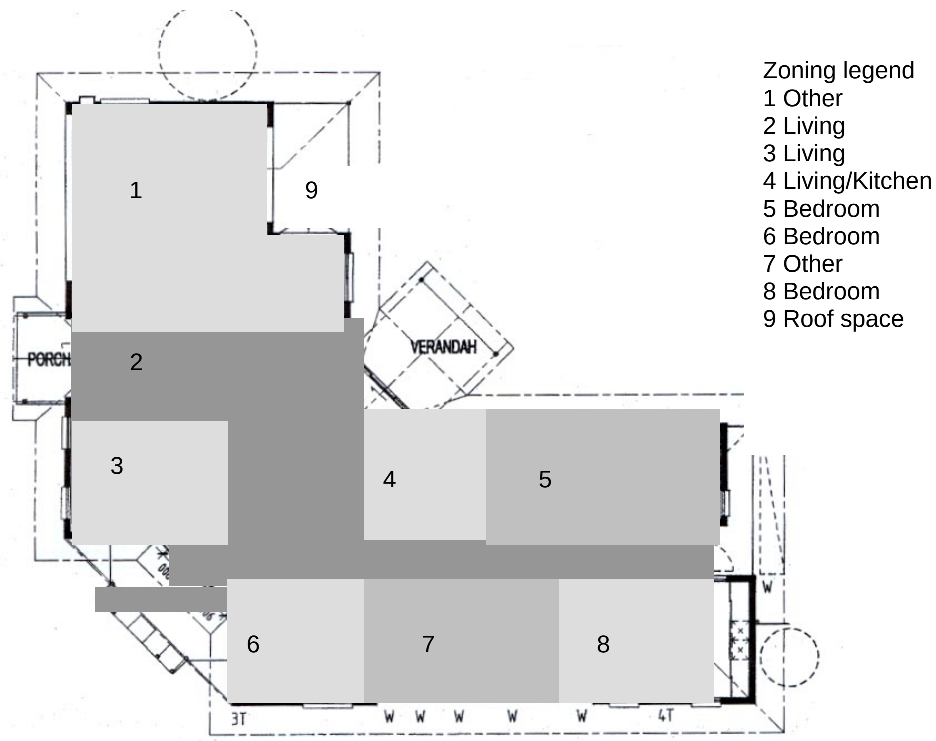
Unfortunately, neither the BERS data files nor reports were available for this study. To highlight the differences between the two programs in more detail, a possible zoning pattern follows:

Figure 8.17 Case study 1 – possible BERS zoning pattern



In this instance, the two living zones and one bedroom are conditioned. The remaining bedrooms and the utility areas are not conditioned.

Figure 8.18 Case study 1 - AccuRate zones



- For Research House, nine zones were selected, including a roof zone that is not offered in BERS. The selected types, and the program assumptions that follow from these selections, are as follows:

- Zones 1 and 7 are 'other'. These zones are occupied during the waking hours; have no occupancy heat gains and are not conditioned.
- Zones 2 and 3 are 'living'. These zones are occupied during the waking hours (0700-2400); have occupancy heating gains associated with several people and equipment such as entertaining or computing equipment. These zones are conditioned. These zones were separated to enable the impact of altering the zone types to be examined.
- Zone 4, kitchen is 'living/kitchen'. This zone is occupied during the waking hours (0700-2400); and has cooking heat gains included. This zone is conditioned.
- Zones 5, 6 and 8 are 'bedroom'. These zones are occupied during the sleeping hours (2400 - 0700) and are conditioned.
- Zone 9, roof, invokes special roofspace model. AccuRate offers both roof and subfloor zones.

Conditioned floor area

In AccuRate, the conditioned floor area is as follows:

Table 8.1 Conditioned floor area

AccuRate	Floor area
Foyer/family/dining/hall	60.00
Lounge	17.37
Kitchen	11.55
Bedroom 1	17.86
Bedroom 2	15.20
Bedrooms 3 and 4	24.50
Conditioned floor area	146.5 (66 %)
Ensuite/toilet/laundry	24.48
Garage/store	48.74
Total floor	219.71

The impact of altering this conditioned area through manipulating the zone type will be examined later in this case study.

Assessing energy efficiency

The absence of the BERS data makes comparison between BERS and AccuRate problematic as it is not possible at this stage to establish the heating, cooling or annual total loads, or the conditioned floor area that these calculations were based upon. It may have been possible to establish the Annual Total Load that equated to a 5 Star Rating at the time that the simulation was undertaken, but this information is not available at this time.

Table 8.2 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	19.1	150.2	169.1	
BERS	Not available	Not available	Not available	5.0
AccuRate	21.0	86.6	107.7	

The comparison between NatHERS, which makes some allowance for ventilation, and AccuRate demonstrates the improvements in ventilation modelling as the energy loads were calculated from the same data set. There is a reduction in both the cooling and annual total loads of approximately 64 MJ/m²/annum, or approximately 57 %.

An examination of later case studies will examine the reduction in both cooling and total loads between BERS and AccuRate. Instead, having established baseline energy loads, this case study will focus on the impact of the energy efficiency that arises from altering the orientation, increasing the external shielding (thereby reducing natural ventilation) and finally, altering the conditioned floor space through changing the zone type.

Impact of orientation on energy efficiency

Figure 8.19 Dwelling orientation simulations starting from assumed north point

Table 8.3 Orientation simulation

Orientation in degrees	Heating Load MJ/m^2/annum	Cooling Load MJ/m^2/annum	Annual Total Load MJ/m^2/annum	Star Rating TBC
0	19.4	83.3	102.7	
45	20.8	87.1	107.9	
90	20.5	85.2	105.7	
135	19.6	80.1	99.7	
180	17.0	80.8	97.4	
225	18.1	81.3	99.3	
270	22.4	81.3	103.7	
315	22.0	79.7	101.7	
Range	5.4	7.4	10.0 (10 %)	

There is only a minor variation of 10.0 MJ/m^2/annum, or approximately 10 %, in the annual total load throughout the range of orientations.

The orientation of the dwelling is determined firstly by the sub-divisional layout and then by the designer. By the time the plans are presented for EER assessment, this aspect of the design process has been concluded and the assessor cannot manipulate the presented orientation. However, other factors can be manipulated with in some cases, significant impact on the resultant EER. Two such factors are the external shielding and the internal conditioned floor areas.

Impact of increased external shielding on energy efficiency

Moderate shielding was selected for the AccuRate simulation. The shielding was increased to heavy to examine the impact on the energy loads that would occur if the external shielding were increased, thereby reducing the extent of natural ventilation. This would seem to replicate conditions as urban densities increase.

The result of this simulation follows:

Table 8.4 Shielding simulation

Thermal program	Heating Load MJ/m^2/annum	Cooling Load MJ/m^2/annum	Annual Total Load MJ/m^2/annum	Star Rating TBC
NatHERS Simple ventilation	19.1	150.2	169.1	
AccuRate As designed orientation Moderate shielding	21.0	86.6	107.7	
AccuRate Heavy shielding	20.9	92.1	113.0	
Range	1.9	5.5 (6 %)	5.3 (5 %)	

For this case study dwelling, increasing the external shielding has a similar impact on both the cooling and total energy loads as altering the orientation, although the cooling and annual total loads are both higher than those achieved by altering the orientation. While the variations are not significant in this instance, the aim of this discussion is to set the parameters for the following case study discussions.

The external shielding assumption is not disclosed in the rating report in either program.

Impact of altering the conditioned floor area

This dwelling has been designed for natural ventilation and AccuRate allows the assessor to select from a range of zone types to suit the expected internal heat loads. In this instance, the large, open foyer, dining, family and hall areas have been altered from zone type 'living' to 'other' to reduce the internal heat load approximate to several people and entertaining and computing equipment. The partially enclosed lounge area remains as zone type 'living' to contain this internal heat load. The impact of this change is as follows:

Table 8.5 Reduced Conditioned Floor Area

AccuRate	Floor area (m^2)
Lounge	17.37
Kitchen	11.55
Bedroom 1	17.86
Bedroom 2	15.20
Bedrooms 3 and 4	24.50
Conditioned floor area	86.5 (39 %)
Foyer/family/dining/hall	60.00
Ensuite/toilet/laundry	24.48
Garage/store	48.74
Total floor	219.71

Table 8.6 Impact of reduced conditioned floor area

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	12.0	192.5	204.4	
AccuRate As designed orientation Moderate shielding	13.2	85.0	98.2	
AccuRate Heavy shielding	13.2	95.4	108.5	

Manipulating the conditioned floor area has resulted in a favourable reduction in both the cooling and annual total loads. Again, while the variations are not significant, the aim of this discussion is to set the parameters for the following case study discussions. The conditioned floor area is disclosed in the rating reports in both programs. However, the importance of its composition and impact cannot be easily interpreted when only one set of data is examined for each dwelling. What is worth noting is that a reduction of 9 MJ/ m²/annum, might 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 the assessor's objective is to increase the star rating.

Thermal program issues arising from case study 1

- The external shielding selection affects the energy efficiency. This selection is not disclosed at present.
- The conditioned floor area is a result of the zone type selections. As the programs become more sophisticated, more selection possibilities emerge. Most selections could be argued as being reasonable, but the assessor presents only one set and so comparisons, such as this and others presented throughout these case studies, cannot be made.
- As a result, there is potential for the conditioned floor area to be manipulated to lower the overall energy loads.

- 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 the assessors' objective is to increase the star rating.
- These issues are a function of the use of the programs and not of the programs themselves.

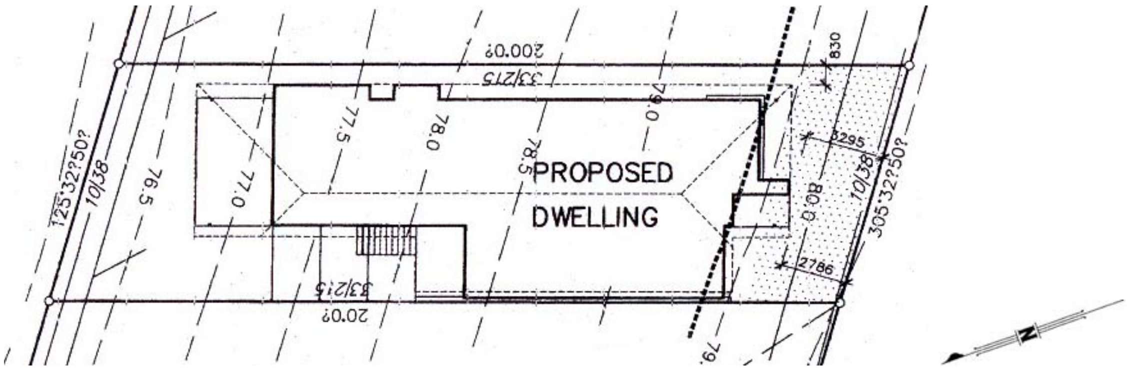
Criteria for possible future tools arising from case study 1

- Altering the orientation in a suburban setting results in a range of 4 % in the annual total load due to increases in the cooling load;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 5 % in the annual total energy load. The cooling and annual total loads both exceed those achieved by altering the orientation alone.
- The impact of heavy shielding through the full range of orientations has not been examined due to time constraints and the number of additional simulations involved.
- External shielding is not disclosed in the ratings reports at present.
- Manipulating the conditioned floor area has potential for reducing the overall energy performance of the dwelling and increasing the EER.

D.3.2 Case study 2 – individual dwelling (Greensmart Home)

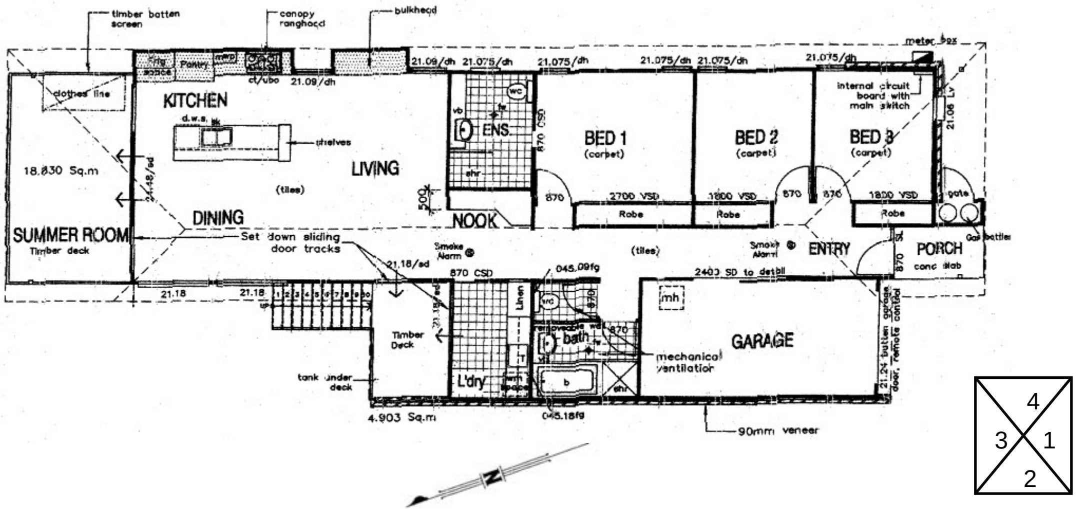
The plans provided for this Greensmart dwelling came from an earlier phase in the design development process and will differ from the constructed dwelling.

Figure 8.20 Site plan



- Small lot 332m² (under 450m² or with a width less than 15m)
- Lot rating – 1 Star

Figure 8.21 Floor plan



- Small (150m²) single storey – elevated slab construction - brick veneer and lightweight clad - 26° metal roof;
- 3 bedroom, 2 pedestal.

Figure 8.22 Elevation 1 - south

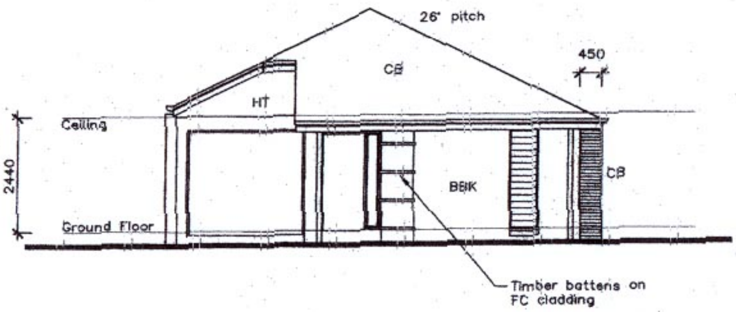


Figure 8.23 Elevation 2 – west

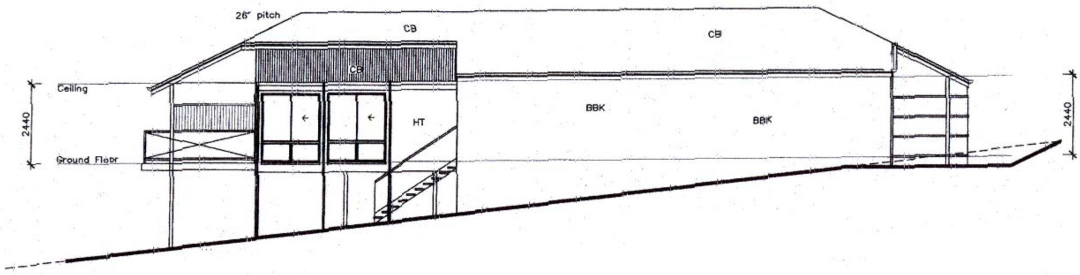


Figure 8.24 Elevation 3 – north

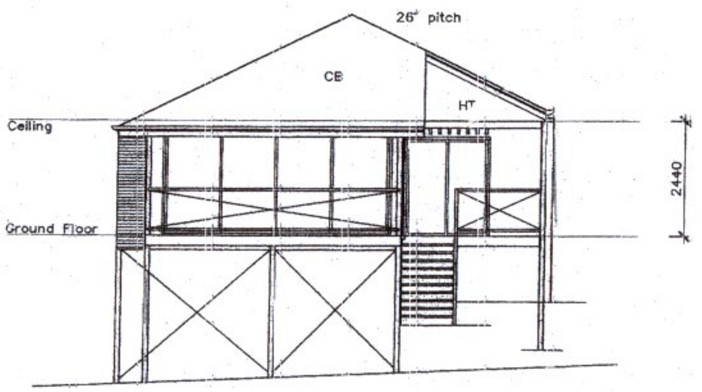
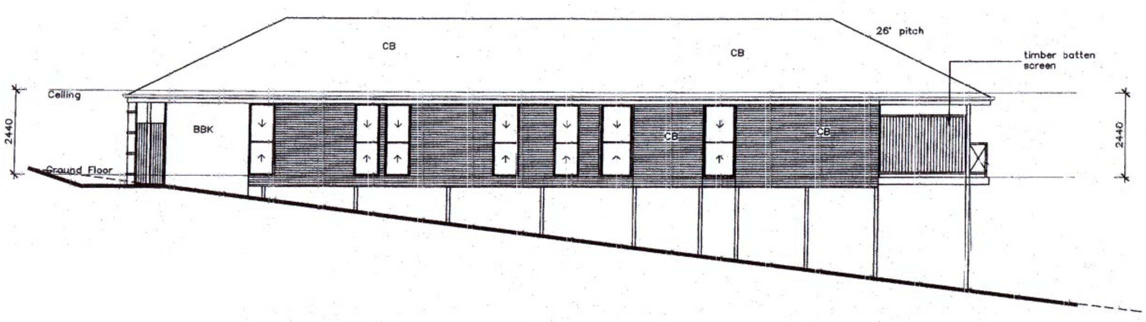


Figure 8.25 Elevation 4 - east



Constructions

Conditioned Floor Areas

The BERS simulation was completed externally and this study only had access to the reports generated.

Table 8.7 Conditioned floor areas

BERS	Floor area (m²)	AccuRate	Floor area (m²)
Living 1	48.0	Kitchen/Living	50.76
		Bedroom 1 and 2	29.18
Bedroom 1	47.3	Bedroom 3	13.23
Conditioned floor area	95.3 (62 %)	Conditioned floor area	93.5 (61 %)
		Ensuite	7.02
		Hall	16.44
		Bathroom	8.93
Service 1	40.5	Laundry	6.82
Service 2	18.0	Garage	19.78
Total internal floor area	153.8	Total internal floor area	152.16

The total conditioned floor area, percentage of conditioned floor area and the rooms that comprise these totals are similar for both programs. Therefore, any variations in the energy loads must arise from variations in the constructions and/or variations in the simulation engines.

External Walls

This is one of the Greensmart Display Homes and has 'above insulation' of R1.5 in the external walls in both programs.

Fans

The external modeller has noted that fans were included in BERS. Fans cannot be included in the AccuRate simulation.

Flooring

The floor is Hebel power panel (AAC) with tiles throughout and carpet in the bedrooms. BERS does not have the option of an aerated concrete floor. Trying to approximate this flooring, the external assessor trialed a number of materials with the following results:

Table 8.8 BERS floor simulations

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
BERS Slab on ground	10.8	41.9	52.7	5.0
BERS Slate or tiled suspended slab No bulk insulation	30.5	177.1	207.5	1.5
BERS Insulated suspended slab R1.5	19.0	87.1	106.1	3.5

Hebel Floor Panelling is 200mm thick and with a total bare R-value of 1.44 as shown in Table 8.9 (CSR Hebel, c 2004). This lends support to the BERS approximation of R1.5 for the flooring insulation.

Table 8.9 Hebel floor paneling

Flooring components	Bare	Carpet
Indoor Air Film	0.16	0.16
6mm carpet		01.0
Air film		0.30
200mm AAC floor panel	1.25	1.25
Outdoor air film	0.03	0.03
Total R	1.44	1.84

Hebel Power Floor is a 75mm thick, lightweight, reinforced panel that has a lower total bare R-value of 0.663 as shown in Table 8.10.

Table 8.10 Hebel power panel

Flooring components	Bare	Carpet
Indoor Air Film	0.16	0.16
6mm carpet		0.10
Air film		0.30
75mm AAC floor panel	0.473	0.473
Outdoor air film	0.03	0.03
Total R	0.663	1.063

It would appear from these tables that the insulation value approximated in BERS may be too high and needs to be reduced to R0.5. This will affect the thermal performance of the dwelling. The range of cooling and annual total loads demonstrates the importance of a comprehensive materials library to enable an efficient and accurate selection of materials.

Unfortunately, only the results were provided for this project, and so further testing of the BERS simulation, was not possible.

The AccuRate the library allows the used to alter the thickness of the materials and this changes its insulating properties.

Garage door - battens

AccuRate allows the assessor to place an opening or a door in an external wall. Under the instructions for opening, the directions are ‘enter the net area of an opening that will be used for ventilation. If there is more than one opening in the wall, enter the total net area. The opening is controlled in the same way as are openable windows’. In this instance, the garage door has been entered as an opening; however, it is constructed from battens and provides permanent ventilation to the dwelling. This ventilation is then controlled by opening or closing the door between the garage and the dwelling. It is not known what impact this design decision could have on reducing the cooling load, or on increasing the heating load if the door between the garage and the dwelling allows draughts.

Internal walls

The other Greensmart homes have windows in internal walls to increase cross ventilation. At present, neither program offers this option, although AccuRate allows internal wall openings to be included. If lightweight, elevated structures perform poorly because of their construction materials, then all design solutions aimed at increasing natural ventilation need to be considered within the thermal programs.

Sub_floor zone - battens

The sub-floor zone can be selected as either 'Enclosed' or 'Open'. ‘Enclosed’ indicates that the only ventilation openings are those required for compliance with building codes, while ‘open’ indicates that additional openings are provided for ventilation. In this instance, the sub-floor area has been set to ‘open’. What is not known at this stage is if the degree of ventilation that is indicated by ‘open’ compares with that provided by battens. At present, it is not possible to construct a material, such as battens, that have an embedded degree of openness, nor is it possible to add additional openings to the sub-floor area. This issue applies to all the high set dwellings and will be discussed further detail in case study 8.

Assessing energy efficiency

Table 8.11 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	43.6	152.9	196.4	
BERS Slate or tiled suspended slab No bulk insulation	30.5	177.1	207.5	1.5
BERS Suspended slab insulation (additional) R1.5	19.0	87.1	106.1	3.5
AccuRate AAC 75mm - total R1.5.	43.9	89.1	133.0	

The BERS range for the correct flooring is 106.1 to 207.5 and this makes comparison with the AccuRate energy loads difficult. However, it is possible that if the floor insulation level was adjusted, that the dwelling would continue to be Deemed to Satisfy (DTS), but would no longer comply using the BER thermal modelling tool. At this point, it must be noted however, that all these modelling assumptions are based on the data supplied for the purposes of this study and that these plans differ from the constructed dwelling.

Impact of orientation on energy efficiency

Figure 8.26 Dwelling orientation simulations starting from assumed north point

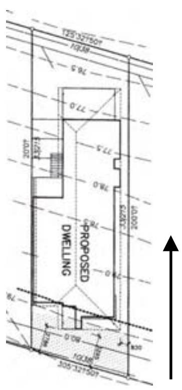


Table 8.12 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m² /annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	45.6	97.1	142.7	
45	43.2	110.8	154.1	
90	39.7	113.5	153.2	
135	35.3	98.8	134.1	
180	34.6	96.0	130.7	
225	36.1	100.5	136.5	
270	37.7	98.1	135.8	
315	49.1	100.0	149.1	
Range	14.5	17.5	23.4 (18 %)	

For this dwelling, the impact of altering the orientation with no subsequent change to the dwelling design, affects both the heating and cooling loads and to a similar degree with the heating varying by 14 MJ/m²/annum and the cooling by 17.5 MJ/m²/annum. The annual total load varies by 23.4 MJ/m²/annum, or approximately 18 %.

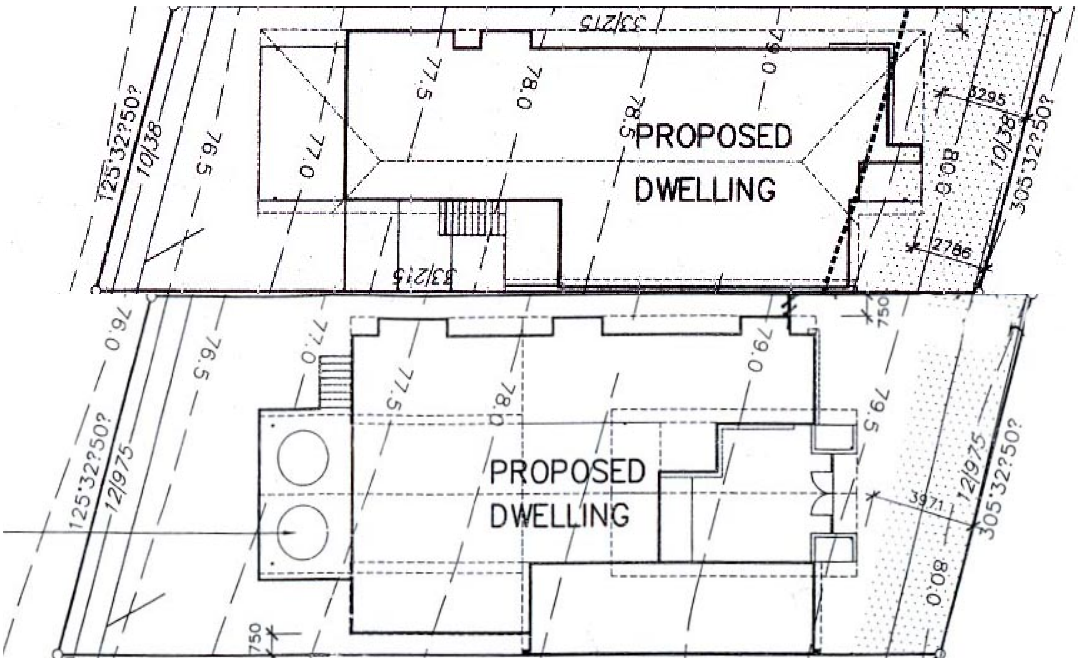
The absence of the area adjusted star ratings makes it difficult to determine what constitutes a significant variation. A significant variation in annual total load could be considered as a variation that causes the star band score to alter by ±½ Star. This has added an unexpected degree of difficulty in interpreting the data and has led to the need to include more detail in each case study in place of a 1-5 star indicator. The point of comparison then must lie within the simulations run for each dwelling and in the totals between the case studies.

Impact of increased external shielding on energy efficiency

Ratings are normally based on the plans supplied and while small sites indicate the potential for neighbouring dwellings to be constructed in close proximity, this information is not usually available at this time of dwelling assessment.

The degree of external shielding is a judgement made by the rater and is based on the individuals knowledge of the development area. This judgement is not disclosed in the ratings process. In this instance, the case study dwelling had been constructed and its proximity to the neighbouring dwelling was known, as indicated in the site plans below.

Figure 8.27 Proximity of case study dwelling (top) with neighbouring dwelling (bottom)



Both programs allow the external shielding to be increased from moderate (suburban) to heavy (inner city). Increasing the shielding reduces natural ventilation. The shielding for the

BERS simulation is not apparent from the data supplied.

The following table illustrates the impact of using AccuRate, which allows for a higher degree of natural ventilation, and then increasing the external shielding to reduce that ventilation:

Table 8.13 Impact of increased shielding on energy efficiency

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	43.6	152.9	196.4	
AccuRate Moderate - suburban	43.9	89.1	133.0	
AccuRate Heavy – inner city	43.9	104.8	148.7 (11 %)	

In this instance, the impact is to increase both the cooling and total annual energy loads by 15 MJ/m²/annum, approximately 11 %. For this case study dwelling, this is similar in both range and annual total load to the impact of altering the orientation.

Worst case scenario

For this case study dwelling, increasing the external shielding is almost as important as poor orientation in terms of the increase in energy loads. The difference is that shielding impacts directly on the cooling load whereas altering the orientation affects both the heating and cooling loads. The following table indicates the possible range of increases in cooling and total energy loads if this dwelling was constructed with the existing levels of insulation, but with varying external conditions. That is, if the current design were treated as a normal project home.

Table 8.14 Individual home as project home

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	43.6	152.9	196.4	
Orientation designed Moderate shielding	43.9	89.1	133.0	
Poor orientation Moderate shielding	43.2	110.8	154.1	
Orientation designed Heavy shielding	43.9	104.8	148.7	
Worst case Poor orientation Heavy shielding	43.1	130.5	173.6	

- Poor orientation with moderate shielding – that is with the orientation determined by the sub-divisional layout, with no subsequent change to the dwelling design – an increase of some 21 MJ/m²/annum;
- As designed orientation/heavy shielding – measuring the impact of increasing urban densities in reducing the natural ventilation the dwelling was designed to capture – increase of 15 MJ/m²/annum.
- Worst case scenario – dwelling sited to conform to a sub-divisional layout that is inappropriate for the design in conjunction with heavy external shielding – increase of 40 MJ/m²/annum, or some 30 %.

Thermal program issues arising from case study 2

- Data on adjoining properties is rarely available at the time of rating the dwelling.
- 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 in the both programs.

- Practice notes relating to small lots and shielding are problematic, as slope angle and direction can also influence access to breezes.
- Given the increase in energy indicated in the heavier shielding, there may be commercial pressures on the rater to select the optimum external conditions for the dwelling.
- Whatever the basis for the shielding assumption, it is not disclosed in the ratings statement.
- The range of cooling and annual total loads demonstrates the importance of a comprehensive materials library to enable an efficient and accurate selection of materials;
- The role of battens in shielding elevated under floor areas needs to be addressed.

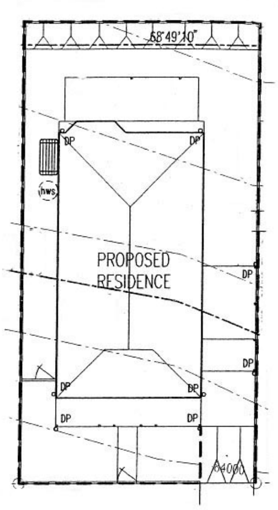
Criteria for possible future tools arising from case study 2

Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling with the newer software has resulted in a decrease of 32 % in the annual total load between NatHERS and AccuRate.
- Altering the orientation in AccuRate resulted in an increase in the annual total load 18 % above the optimum level to a total of 154.1 MJ/m²/annum for the worst orientation;
- The optimum and worst orientations are in the range predicted by the SEDA lot rating tool;
- At the presented orientation, increasing the external shielding from suburban to heavy resulted in an increase of 11 % in the annual total energy load to 148.7 MJ/m²/annum;
- With increased external shielding the annual total load is similar range to that achieved by altering the orientation alone;
- The worst case scenario, that is with the dwelling sited to conform to a sub-divisional layout that is inappropriate for the design in conjunction with heavy external shielding causes an increase of 40 MJ/m²/annum, or some 30 % to a total of 173.6 MJ/m²/annum.
- Finally, reducing the insulation levels to DTS levels was not explored, yet this would be a legal option for any homeowner optioning a demonstration dwelling to suit their requirements.

D.3.3 Case study 3 – project home

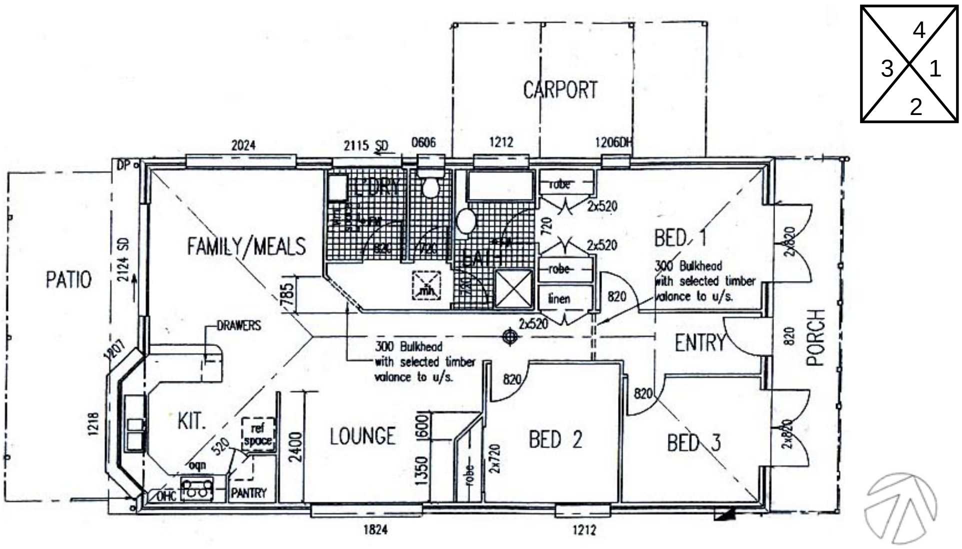
Figure 8.28 Site Plan



- Lot size 300m²- small

- Lot rating – 4 Stars

Figure 8.29 Floor Plan



- Small, 104m², brick veneer on slab, metal roof with 30° pitch
- 3 bedroom, 1 pedestal.

Figure 8.30 Elevation 1 - eastern

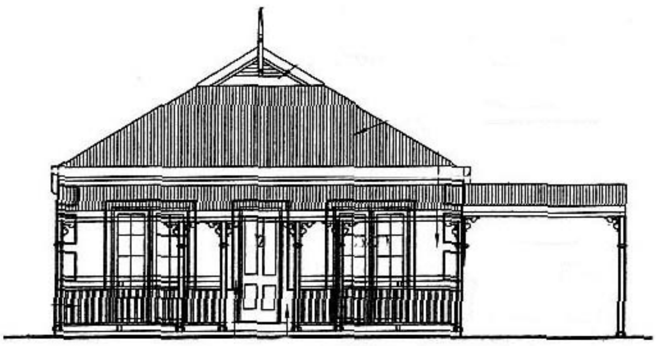


Figure 8.31 Elevation 2 – southern

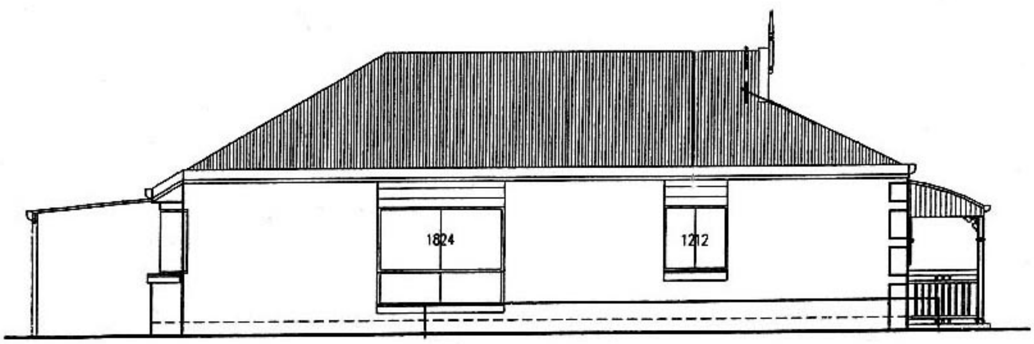


Figure 8.32 Elevation 3 western

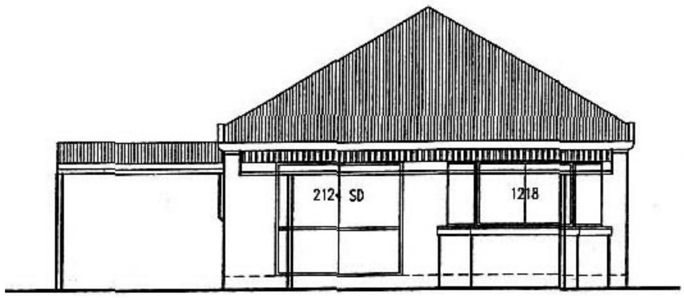
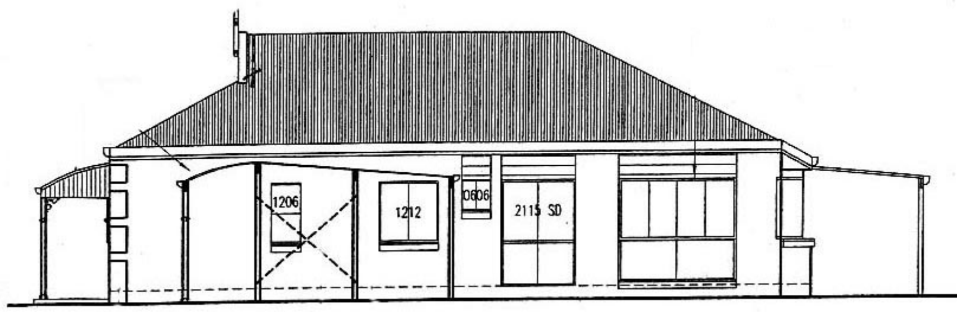


Figure 8.33 Elevation 4 – northern



Constructions

There are no unusual constructions associated with this dwelling.

Table 8.15 Comparison of Conditioned Floor Areas

BERS	Floor area (m²)	AccuRate	Floor area (m²)
Living 1	52.0	Entry/living/kitchen/family	51.90
Sleeping 1	15.8		17.40
		Bedroom 2	9.93
Sleeping 2	18.0	Bedroom 3	9.69
Conditioned floor area	85.8 (85 %)	Conditioned floor area	88.9 (88 %)
Service 1	19.3	Laundry/bathroom	15.52
Total internal floor area	105.00	Total internal floor area	104.42

The conditioned floor areas, and the rooms comprising the total areas, are similar in both programs. Combined with the standard constructions, this means that any variations in the energy loads must arise from differences between the thermal programs.

Assessing energy efficiency

Table 8.16 Thermal Program Comparison

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Complete program	40.2	164.2	205	1.5
NatHERS Simple ventilation	17.0	125.1	142.1	
BERS	29.8	109.8	139.6	3.0
AccuRate	17.3	97.4	114.8	

Modelling the dwellings in the complete version of the NatHERS program was outside the scope of this project and has only been undertaken for selected case studies to highlight the improvement in energy efficiency modelling. The above table shows the significant drop in the cooling and total loads expected when first BERS and then AccuRate make more allowance for natural ventilation.

Impact of orientation on energy efficiency

Figure 8.34 Dwelling orientation simulations starting from assumed north point

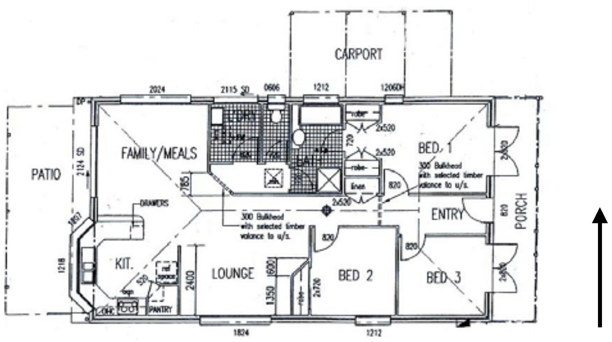


Table 8.17 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	15.8	89.1	104.9	
45	16.0	95.4	111.3	
90	17.8	98.2	116.0	
135	19.9	93.7	113.7	
180	17.5	90.2	107.6	
225	21.5	93.1	114.6	
270	20.1	95.8	115.9	
315	20.3	91.9	112.2	
Range	6.0	9.1	11.1 (11 %)	

For this case study dwelling, altering the orientation impacts on the heating and cooling to a similar degree, with the total energy varying by 11.1 MJ/m²/annum, or approximately 11 %.

Impact of increased external shielding on energy efficiency

This small lot dwelling could be expected to be located in close proximity to neighbouring dwellings, thereby reducing the opportunity for natural ventilation. To replicate these conditions, the shielding was increased in both programs with the following results:

Table 8.18 Impact of increasing external shielding on energy efficiency

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	17.0	125.1	142.1	
BERS Suburban terrain	29.8	109.8	139.6	3.0
BERS Heavy terrain	29.5	109.7	139.2	3.0
AccuRate Moderate shielding	17.3	97.4	114.8	
AccuRate Heavy shielding	17.3	108.5	125.7	

In BERS, increasing the shielding and decreasing the natural ventilation, has a negligible impact on the energy loads.

At the present orientation, in AccuRate the impact of reducing the external ventilation is an increase of 9 to 10 % in the cooling and total loads. However the actual cooling and total energy loads are now 108.5 and 125.7 MJ/m²/annum respectively, which are some 10 MJ/m²/annum higher than the highest totals recorded through altering the orientation alone.

For this dwelling, increasing the external shielding alone has a greater impact on energy efficiency than altering the orientation.

Pre-BCA 2003 performance

The findings for this cases study are bound to raise comment, especially among critics of southern-based thermal simulation tools, so it is worthwhile considering how this dwelling would have rated in the same thermal programs before the recently introduced requirement for R2.5 ceiling insulation.

Table 8.19 Pre BCA 2003 energy efficiency

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	139.4	198.4	337.0	
BERS Suburban terrain	118.4	297.2	415.6	0.5
BERS Heavy terrain	118.0	297.5	415.6	
AccuRate Moderate shielding	140.3	157.9	298.2	
AccuRate Heavy shielding	140.1	176.8	316.9	

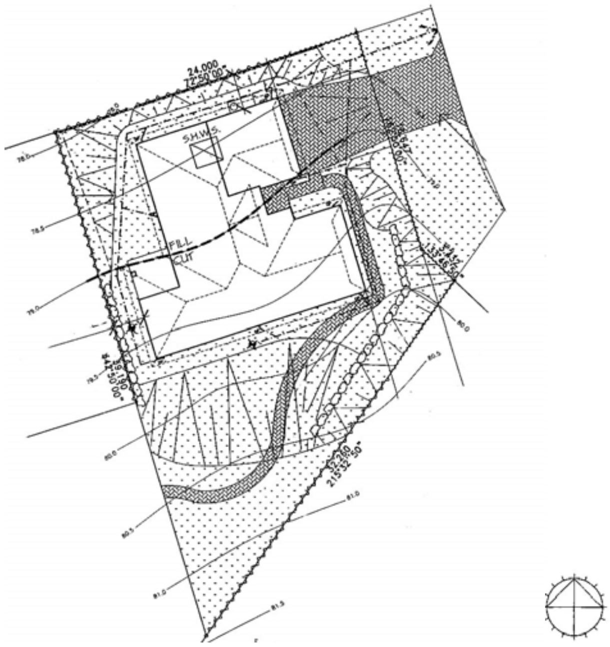
Criteria for possible future tools arising from case study 3

Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling has resulted in a decrease of 20 % in the annual total load between NatHERS and AccuRate.
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 11 % above the optimum level to a total of 116.0 for the worst orientation;
- The optimum orientation was in range predicted by the SEDA lot-rating tool. There were a number of orientations that provided the worst, or close to the worst energy loads, but the overall range in terms of impact on energy loads was small;
- At the presented orientation, increasing the external shielding from suburban to heavy in AccuRate resulted in an increase of 9 % in the annual total energy load to 125.7 MJ/m²/annum, exceeding the cooling and annual total loads achieved by altering the orientation alone;
- In BERS, increasing the shielding and decreasing the natural ventilation has a negligible impact on the energy loads;
- For this dwelling, increasing the external shielding alone has a greater impact on energy efficiency than altering the orientation;
- In AccuRate, removing the ceiling insulation to pre-BCA 2003 standards resulted in an increase in the annual total load of some 250 % to 298.2 MJ/m²/annum.

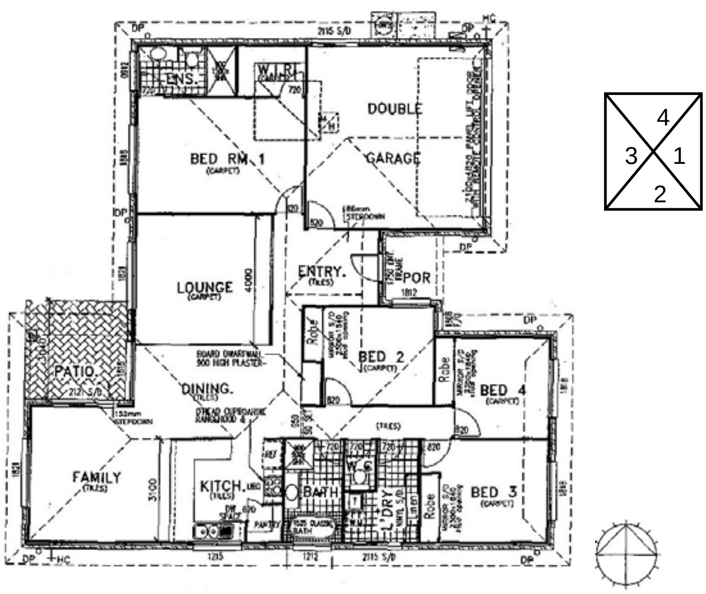
D.3.4 Case study 4 – project home

Figure 8.35 Site plan



- Lot 725m² - large (over 560m²)
- Lot rating – 5 Star

Figure 8.36 Floor Plan



- This dwelling represents a typical suburban family home
- Larger – single storey – 194m² - brick veneer on slab- tiled roof 25º pitch

Figure 8.37 Elevation 1 – east

Figure 8.38 Elevation 2 – south

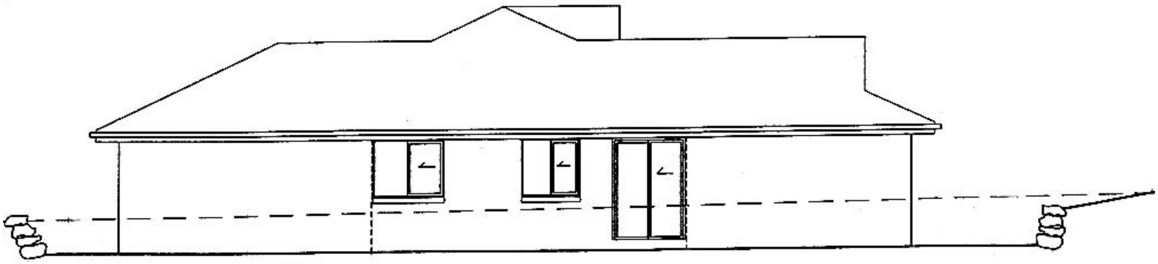


Figure 8.39 Elevation 3 – west

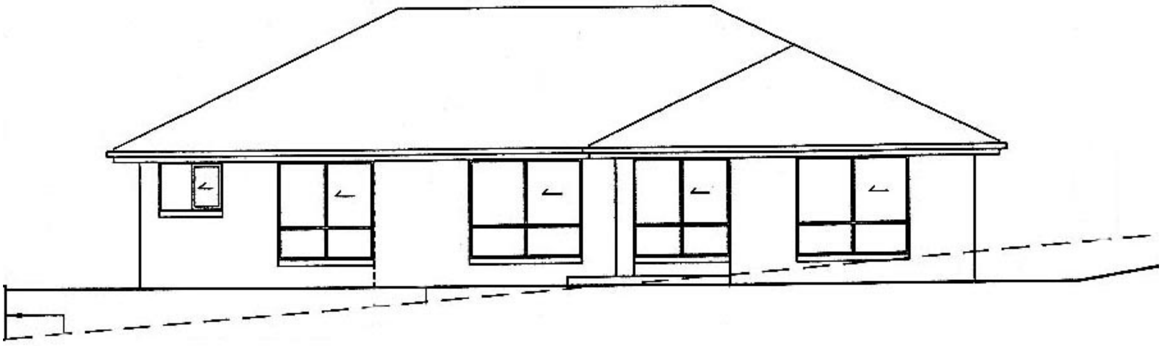
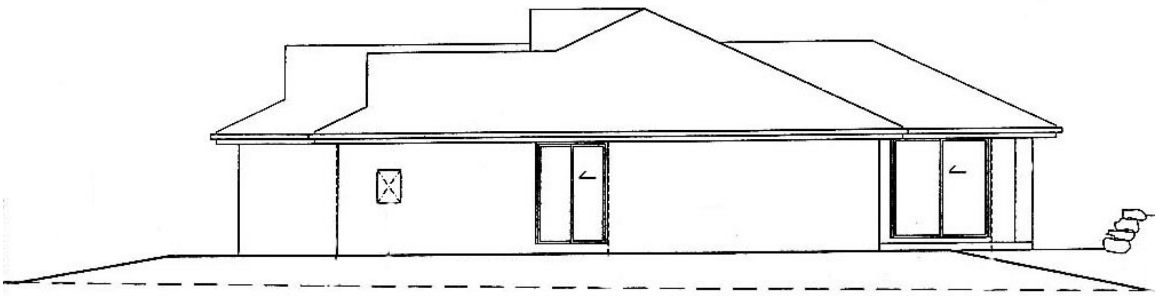


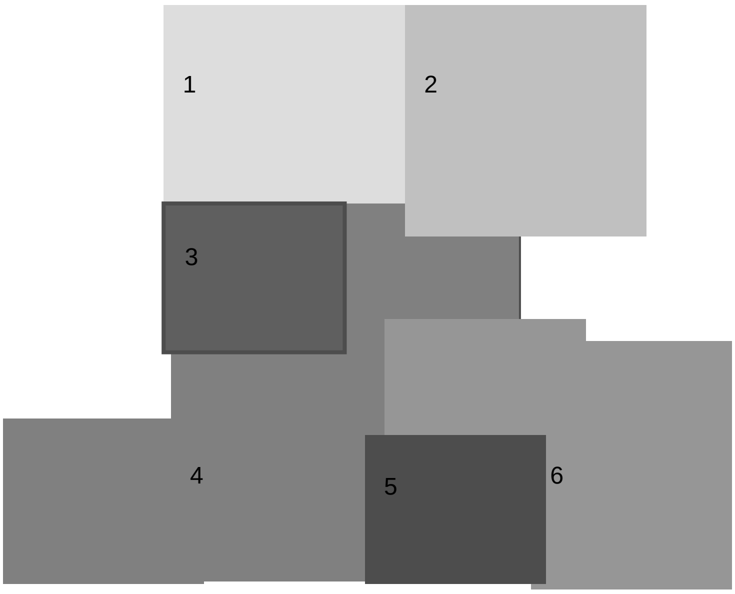
Figure 8.40 Elevation 4 – north



Impact of zoning regimes on assessing energy efficiency

The focus of this case study will be on the differences that arise from the different zoning regimes.

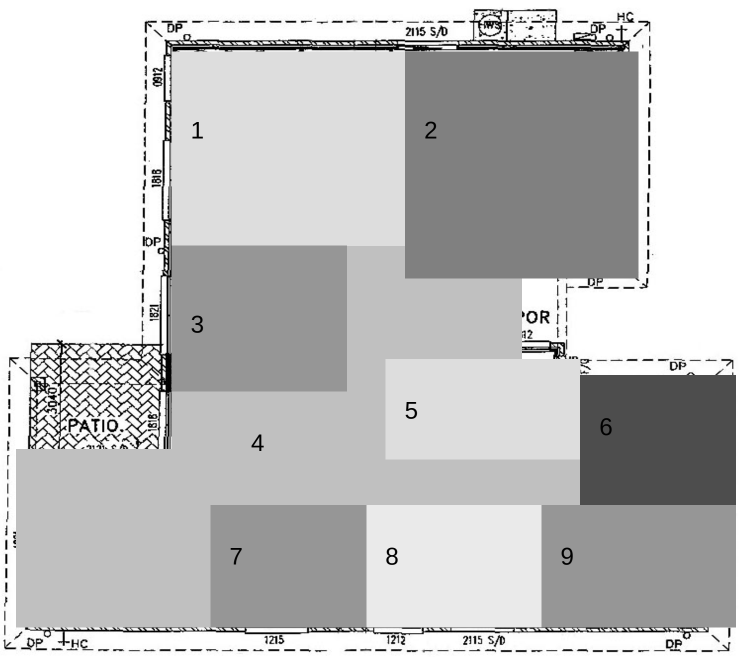
Figure 8.41 Zones - BERS



In conditioned mode, BERS allows the building to be simulated with up to three zones being independently heated and cooled. Only two living areas and one bedroom, or two bedrooms and one living area can be conditioned and this selection is automatic. If there are two living zones, as there are in this instance, these will automatically be selected for conditioning ahead of the second bedroom. For this case study, Sleeping 2 consists of bedrooms 2, 3 and 4, which may be used as a SOHO. The assessor can influence the zoning selection to a limited degree. In this case study, the

- Lounge is a separate zone as it is partially enclosed and has a different flooring (carpet);
- Equally, the kitchen could have been zoned separately because of the heat load.

Figure 8.42 Zones – AccuRate



Ten zones have been selected compared with six possible in BERS V3.2. These include a roof zone that is not available in BERS. The increased number and types of zones enables both the assessor to define more accurately the internal heatloads that need to be ventilated away, while the exact placement of internal walls enables internal barriers to external ventilation to be modelled. It is expected that these increases in data will result in a more comprehensive estimation of the heating, cooling and annual total energy loads.

In this case study, the open plan kitchen, entry, dining and family rooms are all conditioned, but have been zoned to depict differing internal heatloads of kitchen and living as follows;

- Kitchen is separated from family and dining areas to define and contain the internal cooking heat load
- Lounge is separated and zoned as 'living' to define and contain an internal heat load approximate to several people and equipment such as TVs.

Bedrooms 1 – 3 are zoned as bedrooms and conditioned is response to the differing orientations and shading and the internal ventilation barriers. Bedroom 4, which is nearest the entry, has been assumed to be used as a SOHO and has been zoned to 'living' to capture the heatload associated with day time occupancy and the presence of computing equipment and the like.

Table 8.20 Conditioned floor area

BERS	Floor area (m²)	AccuRate	Floor area (m²)
Liv 1	16.0	Lounge	18.23
Liv 2	60.0	Kitchen	12.24
Sleeping 1	25.0	Bed 1	28.04
		Bed 2	12.58
		Bed 3	14.11
		SOHO	10.76
		Entry/Dining/Family	50.08
Conditioned floor area	101.00 (51 %)	Conditioned floor area	146.00 (75 %)
Bed 2	40.0		
Service 1	36.00	Garage	34.20
Ser 2	20.0	Ldry/Bath	14.38
Total internal floor area	197.1	Total internal floor area	194.62

- There is a marked variation in the conditioned floor areas, arising from variations in the program zonings. These variations in zoning affect the conditioned floor area for each simulation and are expected to affect the energy loads. There was a marked variation in the conditioned floor areas (BERS 51 % and AccuRate 75 %), arising from variations in the program zonings.
- The master bedroom is separated from the other three by the living spaces, limiting the area that could be conditioned BERS. The zoning configuration is a judgement and any selection of rooms could be deemed as reasonable.
- The sleeping areas could have been reversed with bedrooms two, three and four named as Bedroom 1. That would have increased the conditioned floor area in BERS to 125m². It would also have involved redrawing those portions of the floor plan in BERS. It is unlikely that an assessor, having made the reasonable judgement to condition the master bedroom ahead of the other three, would then redraw the plan to test the impact on the overall energy levels benefited.
- It is only when comparing the need to make a judgement in BERS with the ease of entering the zones as indicated on the plan, that the limitations and cumulative impact of these judgements become apparent.

Assessing energy efficiency

Table 8.21 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	13.4	188.5	201.8	
BERS	32.0	104.6	132.6	3.0
AccuRate	13.6	141.1	154.7	

The dwelling seems to perform much better in BERS. Possible explanations include:

- AccuRate creates a greater internal heatload that has to be ventilated out of the dwelling, whereas the BERS;
- The BERS zoning regime imposes fewer internal barriers to natural ventilation flow;
- The differences between the zoning in the two programs means that rooms of different orientations are being conditioned.

Impact of orientation on energy efficiency

Figure 8.43 Dwelling orientation simulations starting from assumed north point

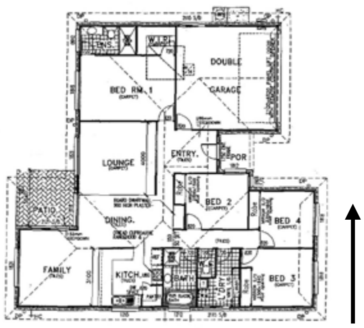


Table 8.22 Orientation simulation - AccuRate

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	13.3	136.8	150.2	
45	13.7	145.7	159.4	
90	10.2	137.3	147.5	
135	10.3	133.8	144.1	
180	11.5	135.5	147.0	
225	15.4	136.6	152.0	
270	15.1	130.7	145.9	
325	14.2	131.0	145.0	
Range	5.2	15.0	15.3 (10.5 %)	

In AccuRate there is a variation of 15.3 MJ/m²/annum, or approximately 10.5 % throughout the orientations. This variation is primarily in the cooling load, with the heating load varying by only 5.2 MJ/m²/annum. The highest annual total load due to altering the orientation alone is 159.4 MJ/m²/annum.

- For this dwelling, increased external shielding has almost the same impact as poor lot orientation;
- However, the cooling and total annual loads exceed those achieved by altering orientation alone.

Impact of increased external shielding on energy efficiency

Heavy shielding could occur if this project dwelling were located on a smaller lot with maximum lot coverage and with similar lot coverage on the adjoining sites, or if located on steep slope using cut and fill techniques that create high retaining walls close to the dwellings.

Table 8.23 Impact of increasing external shielding on energy efficiency

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	13.4	188.5	201.8	
BERS Suburban terrain	32.0	104.6	132.6	
BERS Protected terrain	31.7	104.7	136.4	
AccuRate Moderate shielding	13.6	141.1	154.7	
AccuRate Heavy shielding	13.2	154.3	167.5	

Thermal program issues arising from case study 4

- At the existing orientation, increasing the external shielding, and reducing natural ventilation, has almost no impact on the energy load in BERS. This is an expected result as this is an acknowledged weakness in the earlier program.

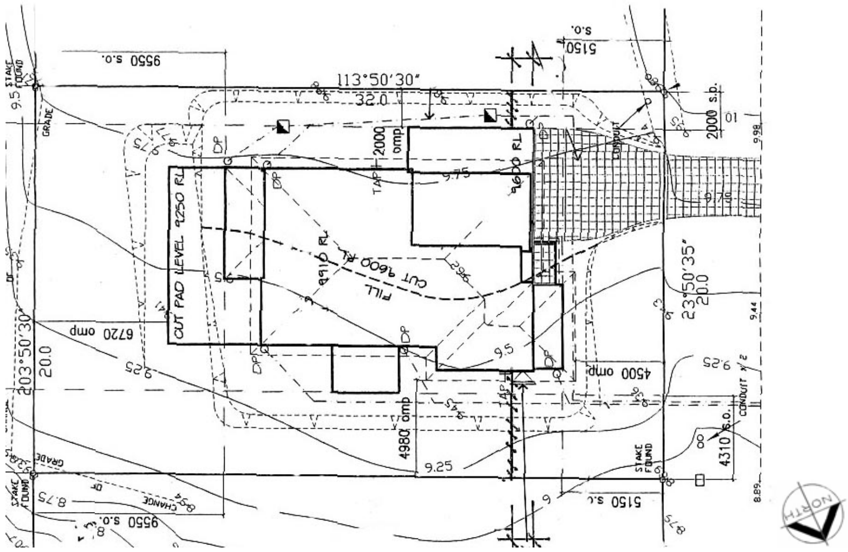
Criteria for possible future tools arising from case study 4

Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling has resulted in a decrease of 24 % in the annual total load between NatHERS and AccuRate;
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 10.5 % above the optimum level to a total of 159.4 MJ/m²/annum for the worst orientation;
- The optimum orientation was in range predicted by the SEDA lot-rating tool. There were a range of orientations that provided the worst or close to the worst energy loads, but the overall range in terms of impact on energy loads was small;
- At the existing orientation, increasing the external shielding, and reducing natural ventilation, has almost no impact on the energy load in BERS. This is an expected result as this is an acknowledged weakness in this program;
- At the presented orientation, increasing the external shielding in AccuRate from suburban to heavy results in an increase of 8 % in the annual total energy load to a total of 167.5 MJ/m²/annum;
- For this dwelling, increasing the external shielding alone has a greater impact on energy efficiency than altering the orientation - the relationship between lot coverage and degree of external shielding needs to be considered;
- This dwelling is similar in size to case study 1, yet at 154.7 MJ/m²/annum, uses 43 % more energy.

D.4 Case study 5 – project home

Figure 8.44 Site plan



- Lot 640m² - large (over 560m²)
- Lot rating - 5 Star

Figure 8.45 Plan – ground floor plan

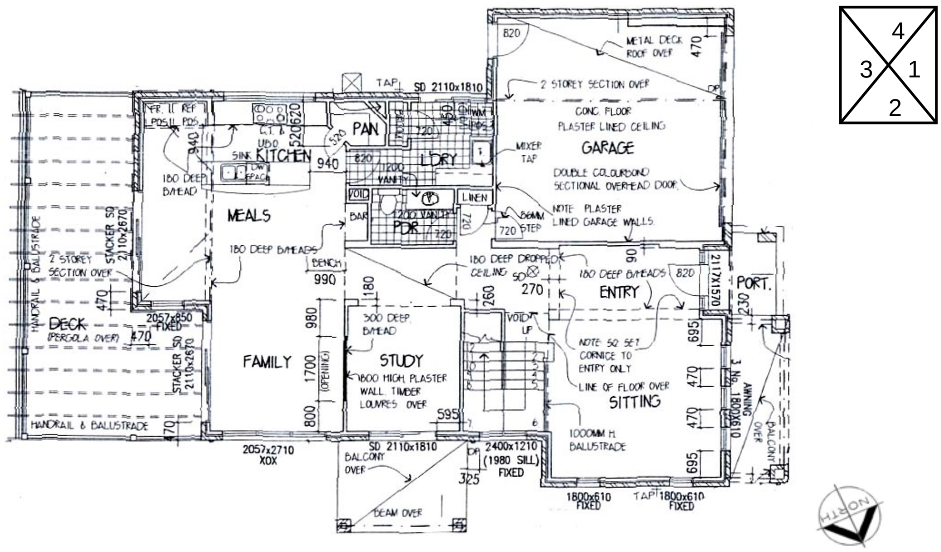
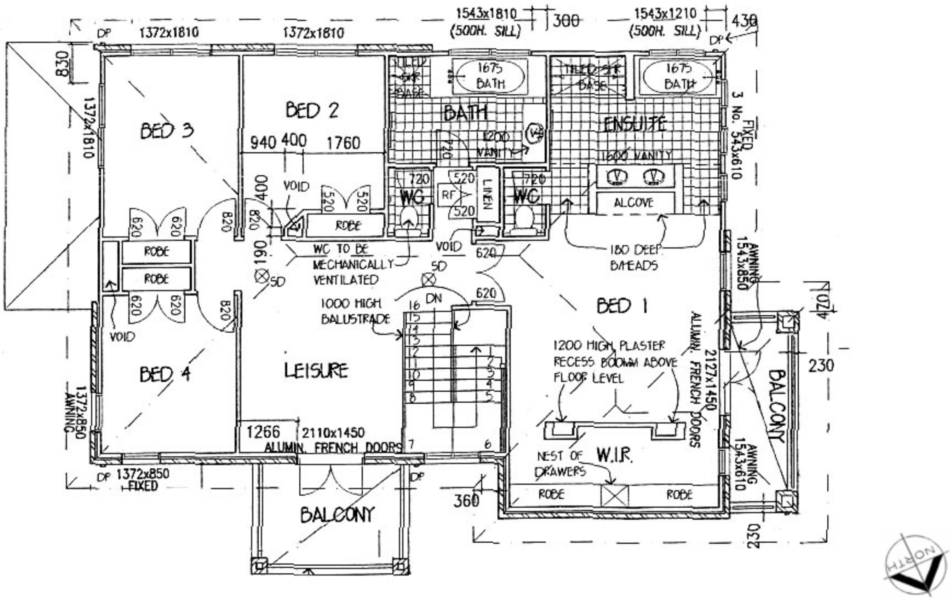


Figure 8.46 Plan – first floor



- Large (287m²) two storey brick veneer on slab with elevated timber floor, metal roof
- 4 bedroom, 3 pedestal, with study, or SOHO on ground floor

Figure 8.47 Elevation 1 - west

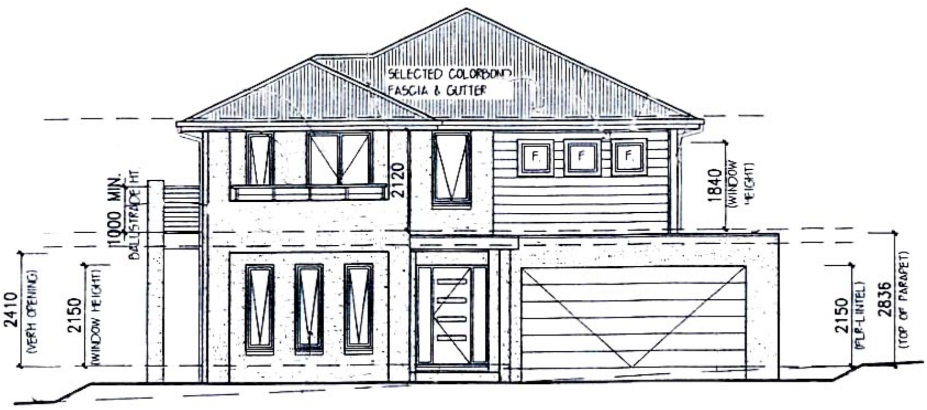


Figure 8.48 Elevation 2 - north

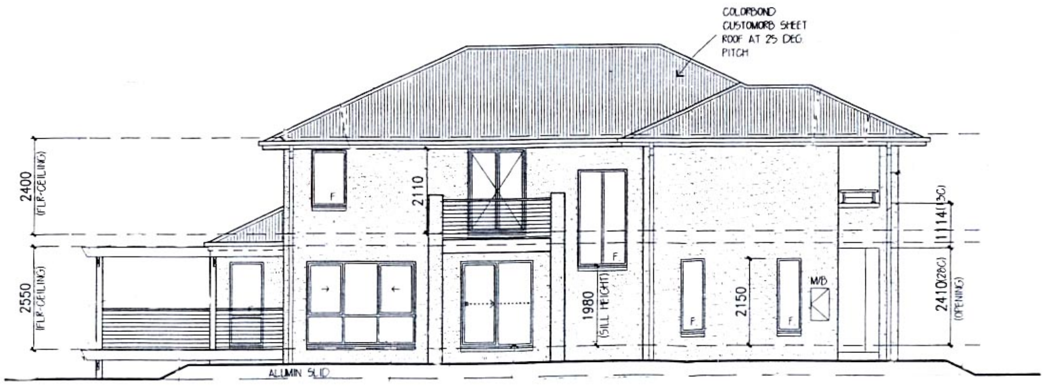


Figure 8.49 Elevation 3 – east

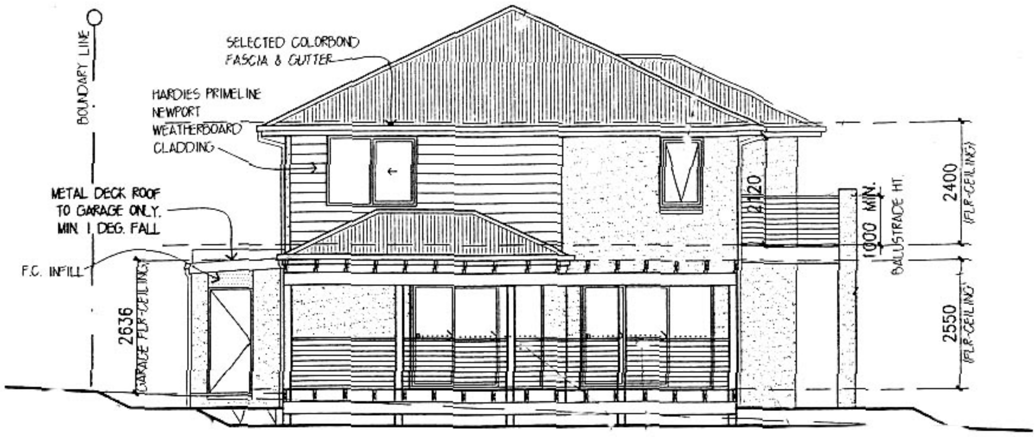
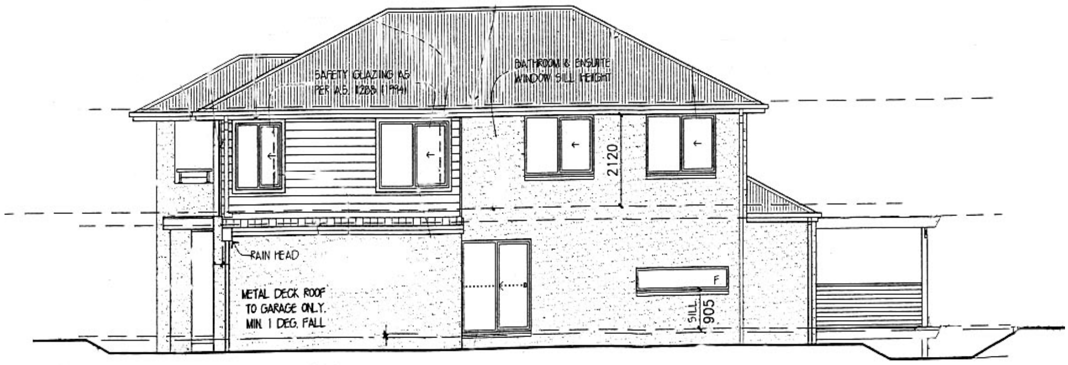


Figure 8.50 Elevation 4 - south



Constructions

There are no unusual constructions associated with this dwelling. It is assumed that the upper floor is timber with carpet or tiles.

Impact of zoning regimes on assessing energy efficiency

Figure 8.51 BERS zoning – ground floor

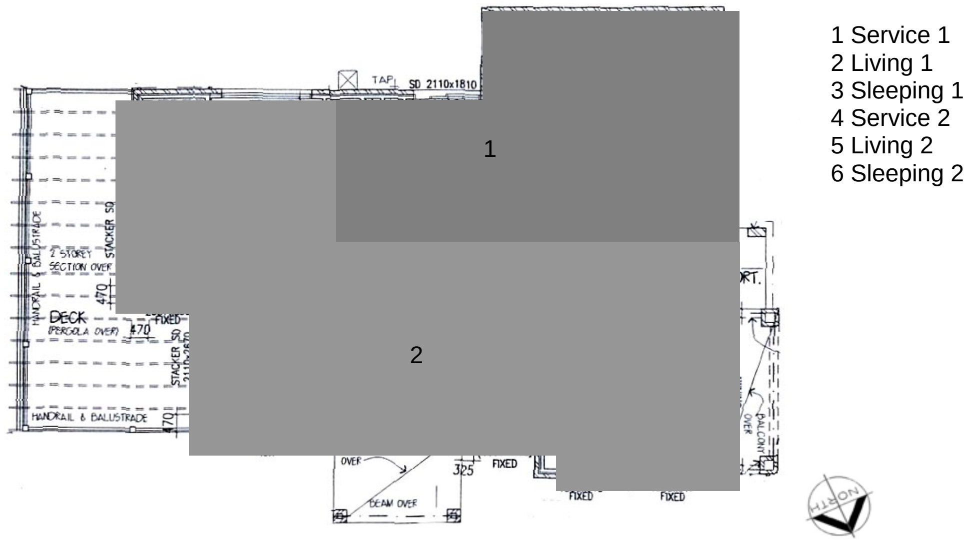
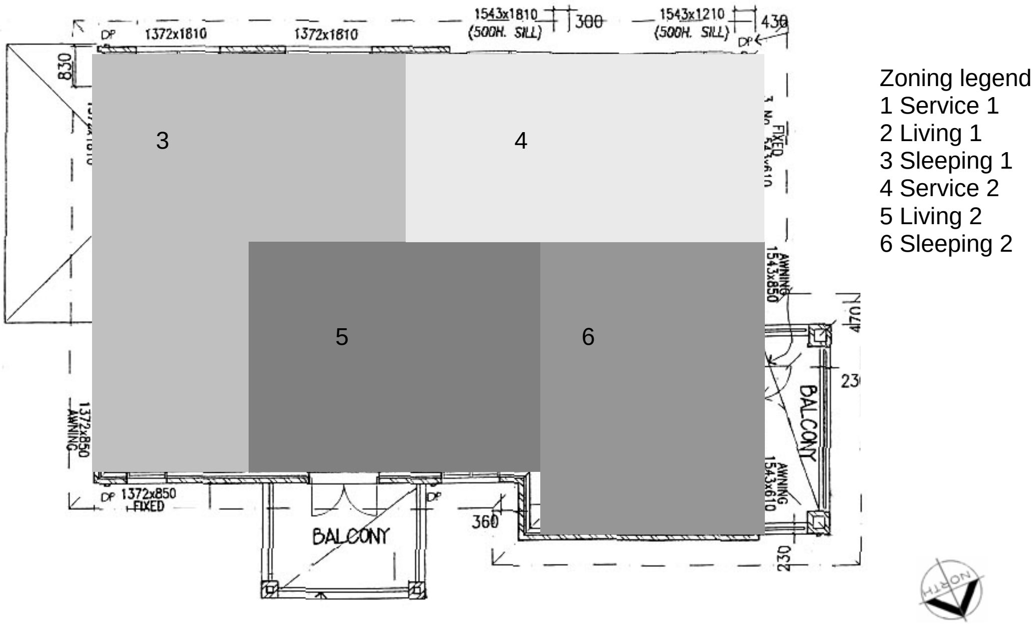


Figure 8.52 BERS zoning – first floor



The limitations imposed by only being able to access six zones in BERS becomes more apparent with larger dwellings as the limited number of zones implies increased internal ventilation paths.

Figure 8.53 AccuRate zoning – ground floor

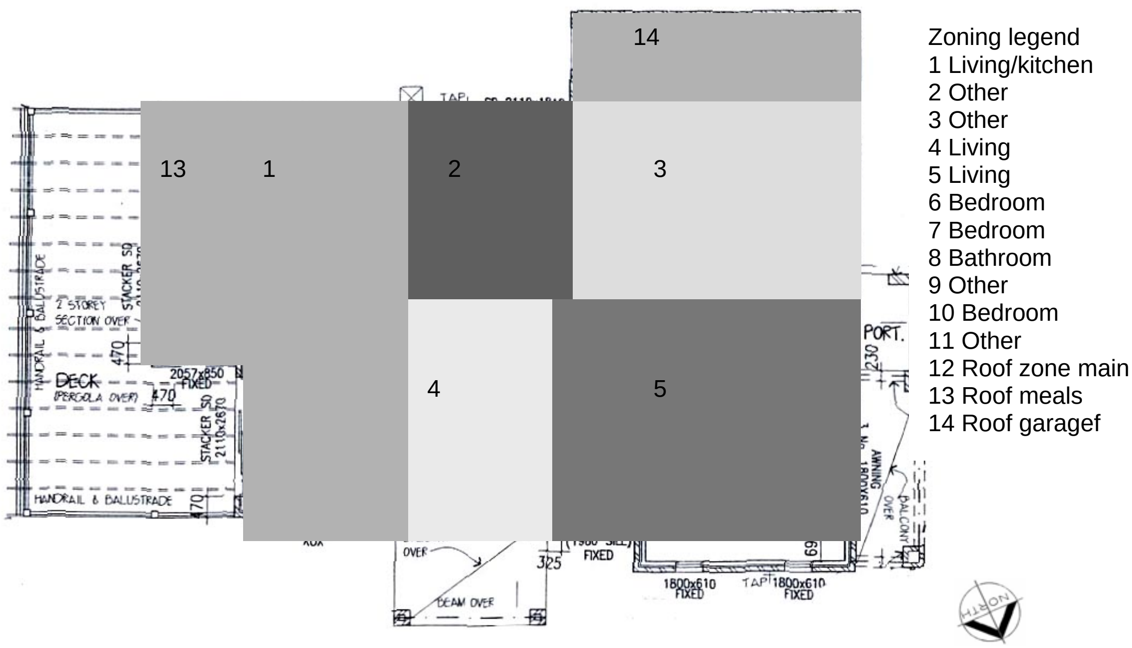
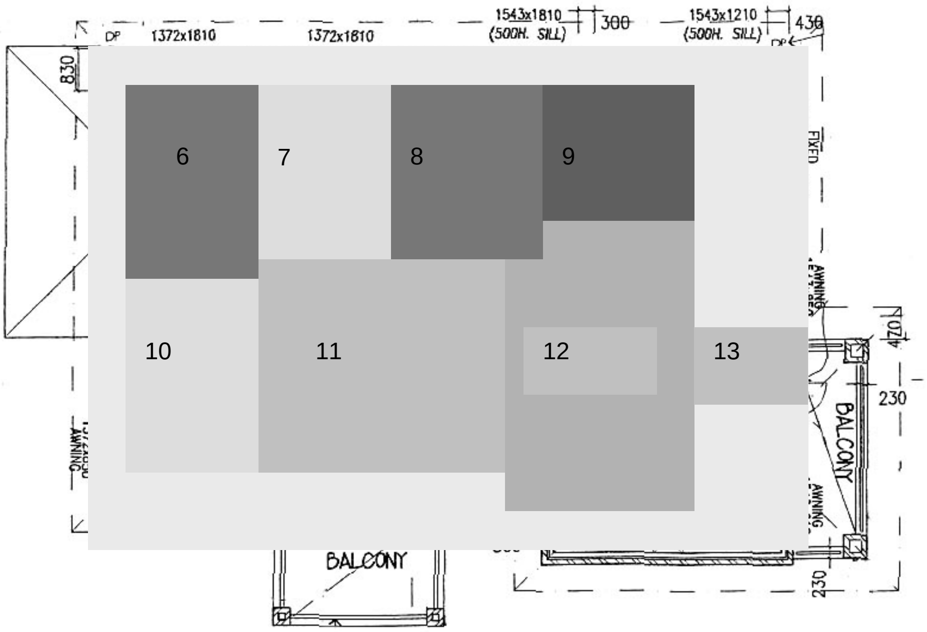


Figure 8.54 AccuRate zoning –first floor



Zoning legend
1 Living/kitchen
2 Other
3 Other
4 Living
5 Living
6 Bedroom
7 Bedroom
8 Bathroom
9 Other
10 Bedroom
11 Other
12 Roof zone main
13 Roof meals
14 Roof garage

Conditioned floor areas

These variations between the programs affect the number and location of the zones that can be conditioned.

Table 8.24 Comparisons of conditioned floor areas

BERS	Floor area (m²)	AccuRate	Floor area (m²)
		Kitchen and dining	44.65
		SOHO	11.47
		Sitting/entry	42.40
Living 1 (level 1)	105.3	Total	98.52
Living 2 (level 2)	30.0	Not conditioned	
Sleeping	27.0	Bedroom 1	32.20
		Bedroom 2	13.40
		Bedroom 3	15.64
		Bedroom 4	14.23
Conditioned floor area	162.3 (56 %)	Conditioned floor area	174.00 (60 %)
See living 2 above		Leisure/hall	28.75
Sleeping	42.0		
Service 1	33.8	Garage	39.00
		Laundry/toilet	15.60
		Bathroom	15.07
Service 2	51.0	Ensuite	13.83
Total internal floor area	289.0	Total internal floor area	286.00

The conditioned floor areas are similar; however, there are variations in the rooms that comprise these totals. In BERS, only one of the two living areas can be conditioned. In AccuRate, all the bedrooms have been conditioned and internal heating loads applied to the kitchen and downstairs sitting area.

Assessing energy efficiency

Table 8.25 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	12.3	160.3	172.6	
BERS	18.1	89.2	107.3	3.5
AccuRate	12.9	107.6	120.5	

The expectation was that the simulations would show a progressive reduction in the cooling and annual loads, reflecting the increased allowance for natural ventilation in AccuRate. The dwelling appears to perform better in BERS and possible explanations include:

- In BERS, the limited number of zones impacts on the way the program interpret barriers in the internal ventilation patterns
- In AccuRate, the internal ventilation barriers are entered and internal heatloads applied.

Impact of orientation on energy efficiency

Figure 8.55 Dwelling orientation simulations starting from assumed north point

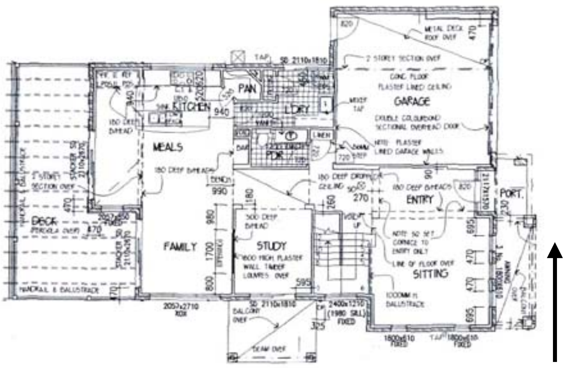


Table 8.26 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	12.0	106.4	118.4	
45	14.5	114.8	129.3	
90	15.5	122.2	137.6	
135	15.3	120.5	135.8	
180	13.6	111.9	125.5	
225	13.2	111.0	124.1	
270	12.9	111.4	124.3	
315	13.7	109.9	123.6	
Range	3.5	15.8	19.2 (16 %)	

Impact of increased external shielding on energy efficiency

Table 8.27 Impact of increasing external shielding on energy efficiency

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	12.3	160.3	172.6	TBA
BERS Suburban terrain	18.1	89.2	107.3	TBA
BERS Protected terrain	18.0	89.1	107.1	TBA
AccuRate Moderate shielding	12.9	107.6	120.5	TBA
AccuRate Heavy shielding	12.8	121.6	134.4	TBA

Increasing the external shielding, and so decreasing natural ventilation, has a negligible impact in BERS.

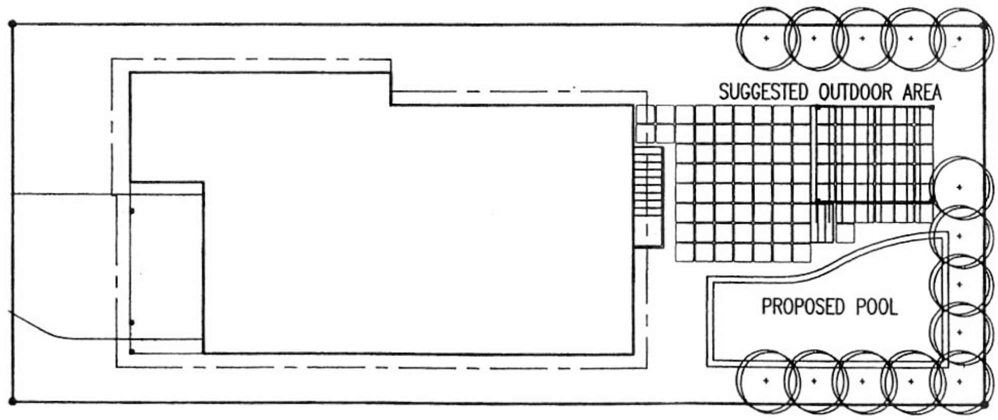
Criteria for possible future tools arising from case study 5

Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling has resulted in a decrease of 30 % in the annual total load between NatHERS and AccuRate.
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 16 % above the optimum level to a total of 137.6 MJ/m²/annum for the worst orientation;
- The optimum orientation was in a range predicted by the SEDA lot-rating tool. There were two orientations that provided the worst, or close to the worst energy loads;
- At the presented orientation, increasing the external shielding and reducing natural ventilation has almost no impact on the energy load in BERS. This is an expected result as this is an acknowledged weakness in this program;
- At the presented orientation, increasing the external shielding from suburban to heavy in AccuRate results in an increase of 12 % in the annual total energy load to a total of 134.4 MJ/m²/annum;
- The impact of increased external shielding is similar in range and total to that achieved by altering the orientation alone.

D.4.1 Case study 6 – project home

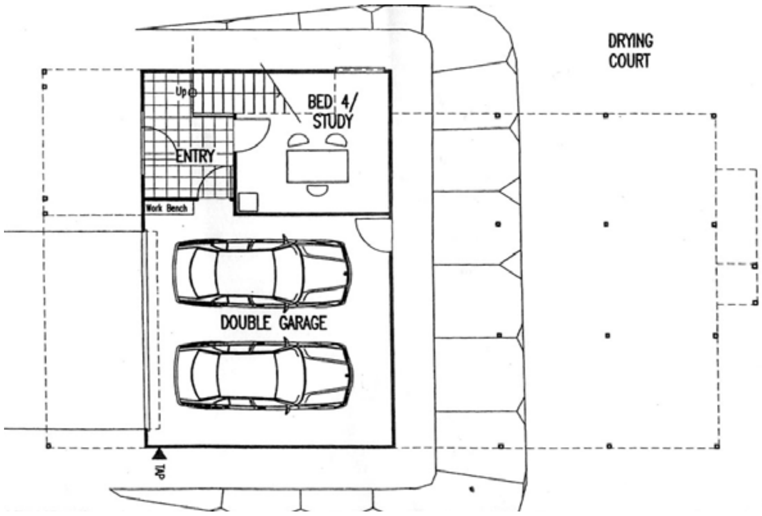
Figure 8.56 Site plan



North not indicated on plan

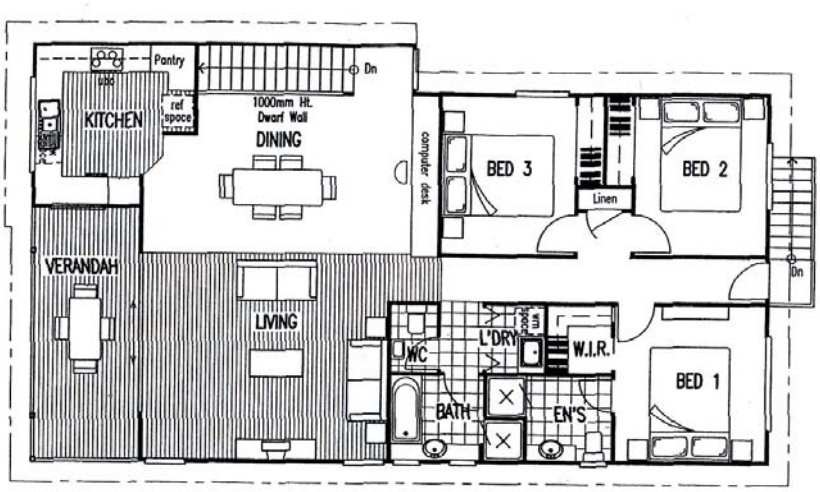
- Small lot - 400m².
- Lot rating unknown as lot orientation is not indicated on the plan

Figure 8.57 Floor plan – ground floor



- 189m² – elevated lightweight construction;
- 3 bedroom, 2 pedestal.

Figure 8.58 Floor plan – level one



Elevations were not provided for this plan

Constructions

There are no unusual constructions associated with this dwelling.

Table 8.28 Conditioned Floor Areas

BERS	Floor area (m²)	AccuRate	Floor area (m²)
Living 1	12.3	Kitchen	12.25
Living 2	56.8	Living/dining	55.75
		Bedroom 1	14.5
		Bedroom 2	12.25
Bedroom 1	40.3	Bedroom 3	12.25
		Bedroom 4/SOHO	8.75
Conditioned floor area	109.8 (60 %)	Conditioned floor area	115.75 (66 %)
Bedroom 2/SOHO	9.8	See above	
		Ensuite/ Bathroom/laundry	15.25
Service 1	44.3	Garage	33.00
Service 2	17.5	Entry	11.25
Total internal floor area	180.8	Total internal floor area	175.25

The issues arising from the different zoning regimes and their impact on the energy loads have been discussed in detail in earlier case studies. In AccuRate, the downstairs bedroom is being treated as a SOHO with a zone type of 'living' indicating a heatload equivalent to equipment such as computers. This zone is conditioned, resulting in the larger conditioned floor area in AccuRate.

Assessing energy efficiency

Table 8.29 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	64.9	228.1	293.0	
BERS	72.0	125.6	197.6	1.5
AccuRate	65.9	175.2	241.1	

The minimum additional R-value for insulation for weatherboard construction in Queensland is 0.53. In the absence of detailed construction data, it is assumed that selecting a ventilated, reflective material with a low emissivity equates with this R-value. It would be helpful if AccuRate offered an R-value selection for foil type insulating materials.

Impact of orientation on energy efficiency

Figure 8.59 Dwelling orientation simulations starting from assumed north point

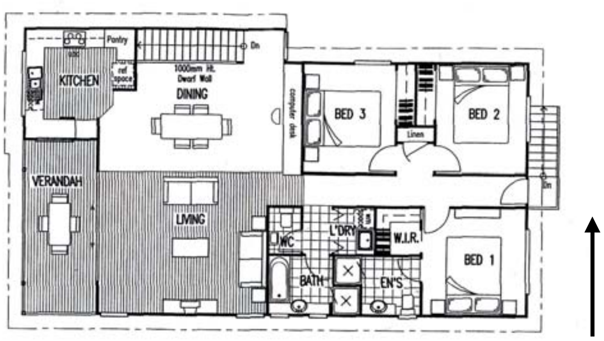


Table 8.30 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	65.9	175.2	241.1	
45	72.0	182.5	254.6	
90	73.2	170.2	243.4	
135	65.8	175.5	241.4	
180	63.9	170.5	234.4	
225	67.4	149.4	216.7	
270	67.2	152.3	219.5	
315	69.5	168.2	237.6	
Range	9.3	33.1	37.9 (17 %)	

For this dwelling, increasing the external shielding at the present orientation will have a similar impact as the worst orientation.

Impact of increased external shielding on energy efficiency

Figure 8.60 Impact of increased shielding on energy efficiency

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	64.9	228.1	293.0	
BERS Suburban shielding	72.0	125.6	197.6	
BERS Protected	71.4	125.3	196.7	
AccuRate Moderate shielding	65.9	175.2	241.1	
AccuRate Heavy shielding	65.6	193.8	259.4	

As with case studies 4 and 5, the dwelling seems to perform much better in BERS. Possible explanations include:

- There was some variation in the conditioned floor areas (BERS 60 %, AccuRate 66 %), arising from variations in the program zonings;
- In AccuRate, the downstairs bedroom is being treated as a SOHO with a zone type of 'living' indicating a heatload equivalent to equipment such as computers. This zone is conditioned;
- In addition, the zone type of living/kitchen creates a greater internal heatload that has to be ventilated out of the dwelling;
- The bedroom and bathroom areas are located over an open sub-floor area. In AccuRate, this area is considered as 'open air', that is, this area is subject to outside temperature variations;
- It is not know what assumptions BERS makes for such areas;
- This lightweight dwelling will be more subject to the external temperature variations, as indicated by the higher heating and cooling loads;
- As the dwelling is under 200 m², the annual total load will be penalized by the large area bias in both programs;

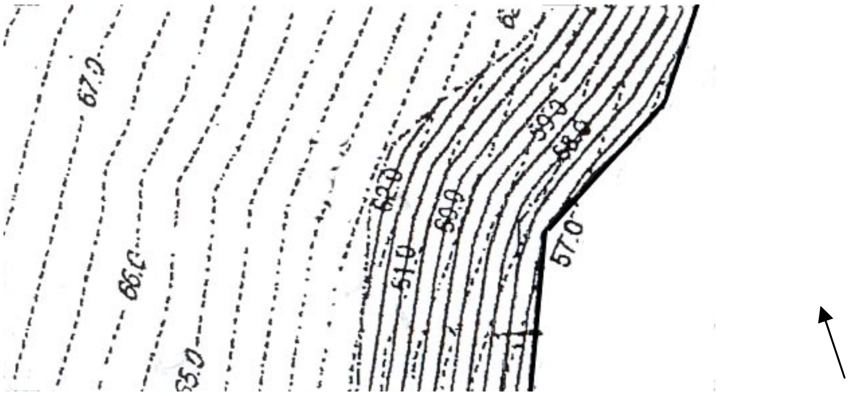
Criteria for possible future tools arising from case study 6

Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling has resulted in a decrease of 18 % in the annual total load between NatHERS and AccuRate.
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 17 % above the optimum level to a total of 254.6 MJ/m²/annum for the worst orientation;
- The optimum and the worst orientations were outside the range predicted by the SEDA lot rating tool;
- At the existing orientation, increasing the external shielding and reducing natural ventilation has almost no impact on the energy load in BERS. This is an expected result as this is an acknowledged weakness in this program and will not be re-examined in any of the following case studies;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 7 % in the annual total energy load to a total of 259.4 MJ/m²/annum;
- The impact of increased external shielding is similar in total to that achieved by altering the orientation alone.

D.4.2 Case study 7 – project home

Figure 8.61 Site plan



- Lot 903m² - large (over 560m²)
- Slope 18 %
- Lot rating – 5 Star

Figure 8.62 Plan – lower ground floor

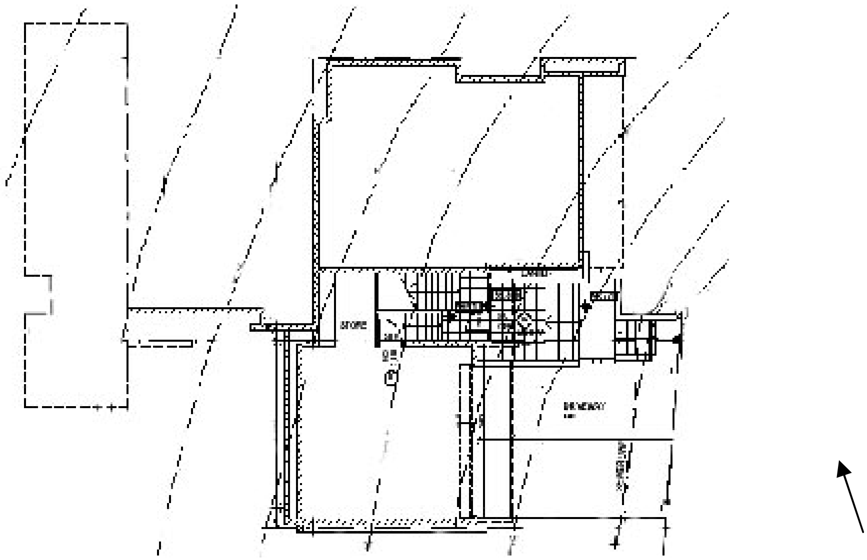


Figure 8.63 Plan – Ground floor

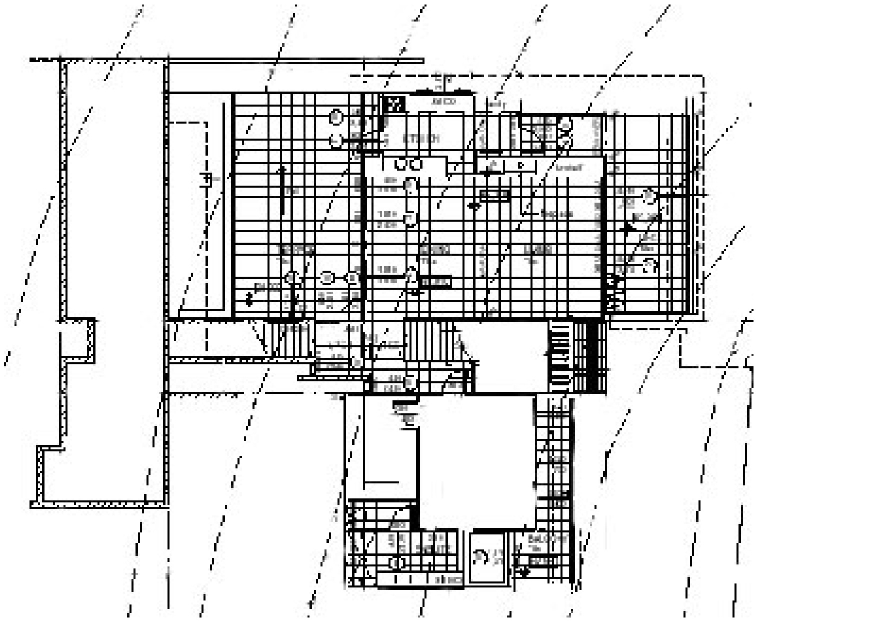
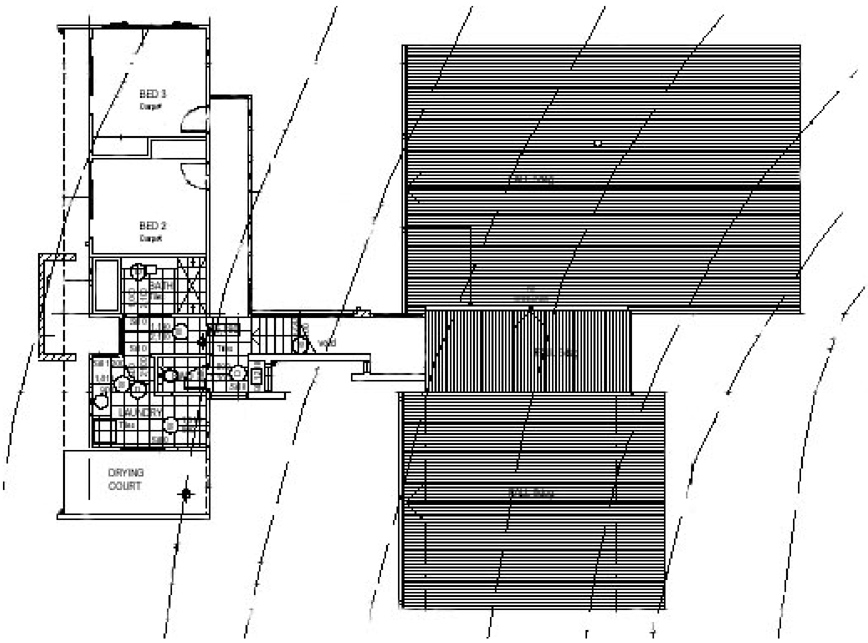


Figure 8.64 Plan – upper level



- Three levels on a steeply (18°) sloping site
- Blockwork on slab lower floor, lightweight external walls on upper levels, metal roof with minimal (5º) pitch
- Large (263m²), 3 bedroom, 2 pedestal.

This split level dwelling with large expenses of glazing to capture views and breezes is the type of dwelling design that is seeking to respond to the challenges imposed by increasingly steep slopes and restrictions on cut and fill techniques.

- It was assumed that the garage floor is a concrete slab and that the upper level floors are timber.
- The difference between this dwelling and case study 6 is that the floors are assumed to close to the slope and the under-floor area is set to 'ground'.

Figure 8.65 Elevation 1 - eastern

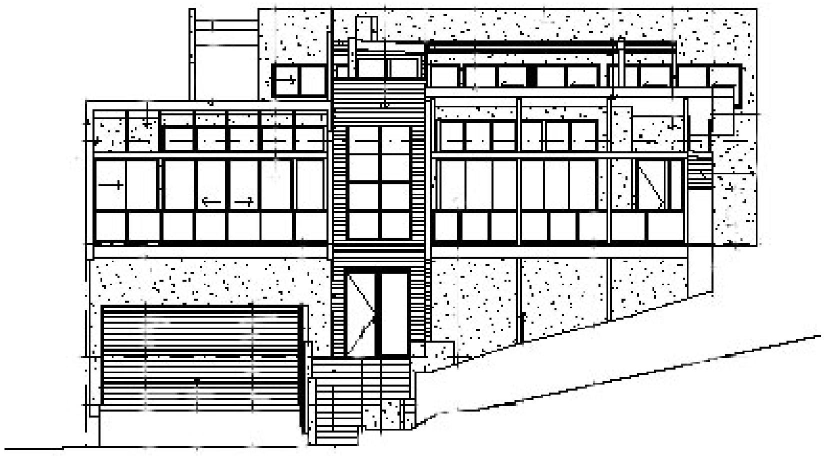


Figure 8.66 Elevation 2 - southern

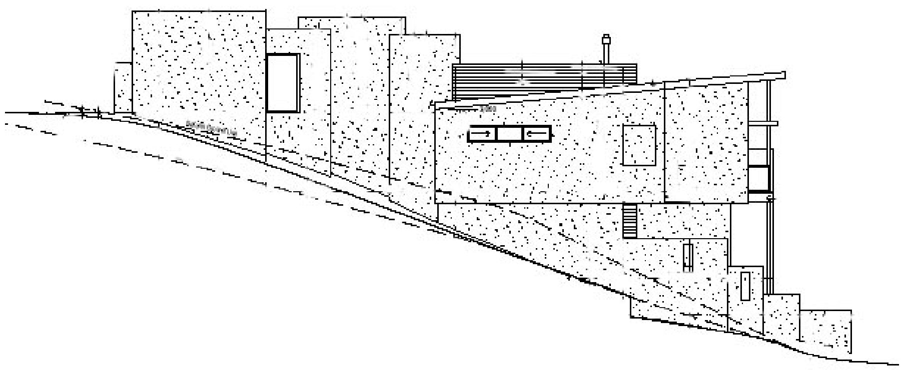


Figure 8.67 Elevation 3 - western

Figure 8.68 Elevation 4 - northern

Constructions

External walls

Blockwork to lower level, with rendered fibre cement and timber in upper level external walls. In Queensland, fibre cement sheeting requires added insulation of R0.6 to attain the minimum R1 required for the wall.

In BERS, the external walls were cavity panel with R0.6 insulation. It was not possible to determine the R-value of the foil insulation materials in AccuRate as this data was not supplied. The lowest emissivity was selected. It is not known if these are equivalent selections, however they are reasonable selections, given the lack of construction data on plans and the limits of the thermal engines.

Table 8.31 Conditioned floor areas

BERS	Floor area (m²)	AccuRate	Floor area (m²)
Living 1	68.00	Entry/living/kitchen/family	62.87
Sleeping 1 (includes ensuite)	42.0	Bedroom 1	31.68
		Bedroom 2	13.11
Sleeping 2	35.0	Bedroom 3	15.01
Conditioned floor area	145.0 (56 %)	Conditioned floor area	122.67 (46 %)
		Ensuite	13.20
		Garage	50.38
Service 1	57.0	Stair/passage	53.5
Service 2	56.50	Laundry/bathroom	23.56
Total internal floor area	258.5	Total internal floor area	263.41

- There are variations in the total floor area and conditioned floor areas arising, as before, from the differing data entry methods in the two programs.
- The ensuite adjacent to the main bedroom and the access passageways adjacent to the upper level bedrooms, are not conditioned in AccuRate.

Assessing energy efficiency

Table 8.32 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	44.5	267.3	311.8	
BERS	113.1	301.6	414.7	0.5
AccuRate	47.8	137.0	184.8	

It is not know why the heating, cooling and annual total loads in BERS exceed those achieved in NatHERS. Possible explanations include:

- There may be problems with the AccuRate findings as the simulation ran with an error report 'problem with vertical alignment of zones';
- The impact of the limited data that can be entered in BERS becomes more apparent in larger and more complex dwellings.

Impact of orientation on energy efficiency

Figure 8.69 Dwelling orientation simulations starting from assumed north point

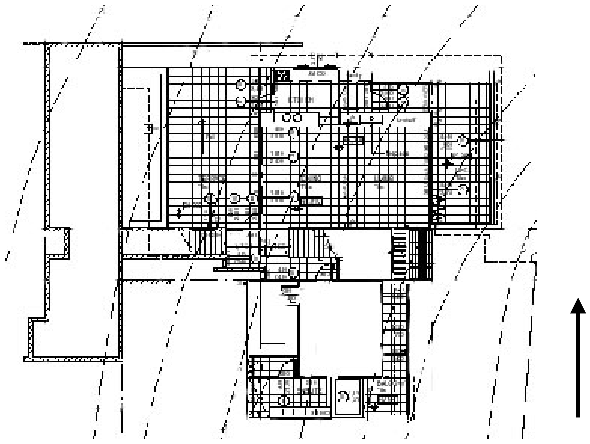


Table 8.33 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	57.3	156.3	223.7	
45	58.3	140.3	198.7	
90	56.5	123.3	180.8	
135	59.8	134.6	194.4	
180	59.7	134.5	194.2	
225	72.5	150.8	223.2	
270	68.4	151.7	220.1	
315	65.5	173.8	239.2	
Range	11.9	49.5	45.0 (23 %)	

There is significant variation in the cooling and annual total loads for this case study dwelling.

Impact of increased external shielding on energy efficiency

Table 8.34 Impact of increased shielding on energy efficiency

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	44.5	267.3	311.8	
AccuRate Moderate	47.8	137.0	184.8	
AccuRate Heavy	47.4	165.5	212.9	

Increased external shielding for a dwelling of this size and on a large lot is unlikely, unless the orientation, such as a west-facing slope, shielded the dwelling from cool breezes.

Thermal program issues arising from case study 7

- There may be problems with the AccuRate findings as the simulation ran with an error report 'problem with vertical alignment of zones';
- The impact of the limited data that can be entered in BERS becomes more apparent in larger and more complex dwellings;
- For these complex settings, dwelling designers require a tool that will enable them to test the energy efficiency of a variety of insulating and shading devices at the design development stage, rather than reacting to an inappropriate rating at a later stage.

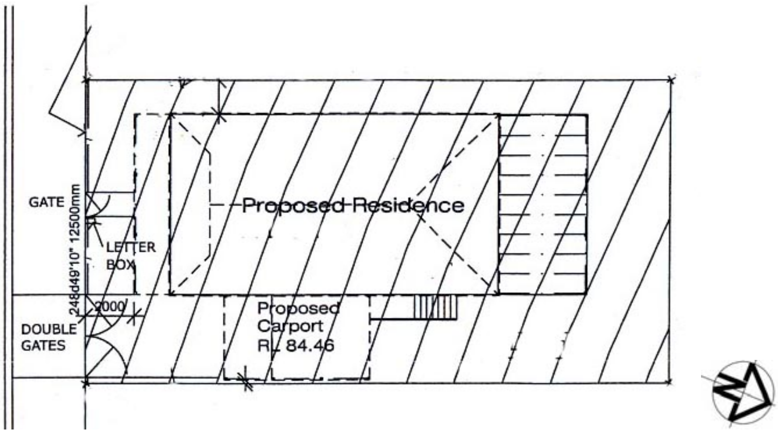
Criteria for possible future tools arising from case study 7

Combining sub-division and dwelling performance, the main findings from this case study were;

- Improved ventilation modelling has resulted in a decrease of 41 % in the annual total load between NatHERS and AccuRate.
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 23 % above the optimum level to a total of 239.2 MJ/m²/annum for the worst orientation;
- The optimum and worst orientations are in the range predicted by the SEDA lot rating tool;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 15 % in the annual total energy load to a total of 212.9 MJ/m²/annum;
- The impact altering the orientation alone is more significant than that of altering the external shielding;
- For these complex dwellings, designers require a tool that will enable them to test the energy efficiency of a variety of insulating and shading devices at the design development stage, rather than reacting to an inappropriate rating at a later stage.

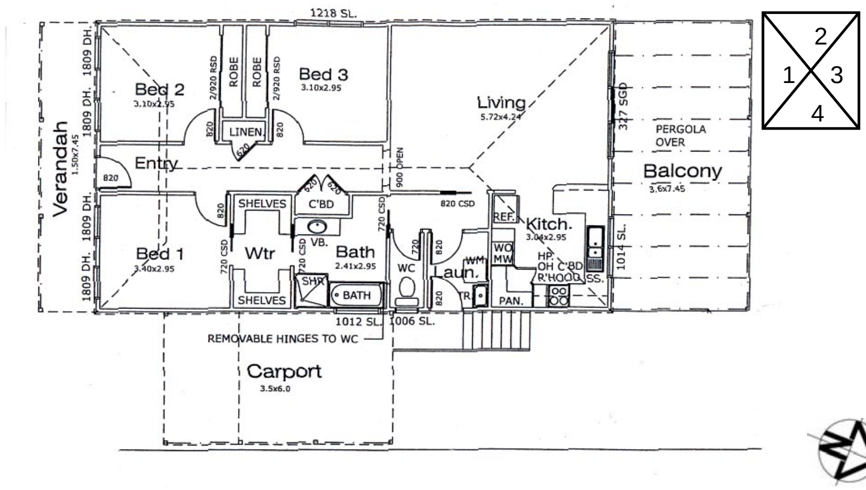
D.4.3 Case study 8 - pre-fabricated dwelling

Figure 8.70 Site plan



- Lot 261m² - small (under 450m²)
- Lot rating – 3 Star

Figure 8.71 Floor plan



- Small, single storey, 100m²
- Elevated, lightweight construction, metal roof 25º pitch
- 3 bedroom, I pedestal.

Figure 8.72 Elevation 1 – south

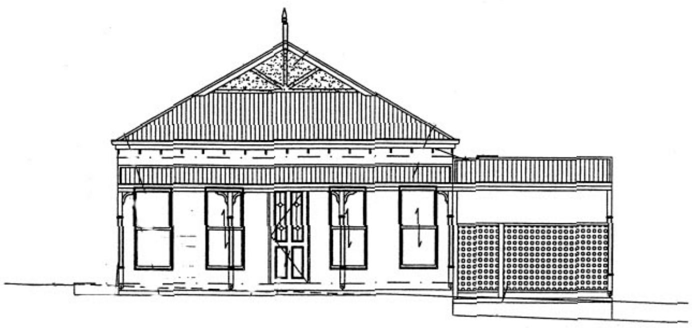


Figure 8.73 Elevation 2 - west

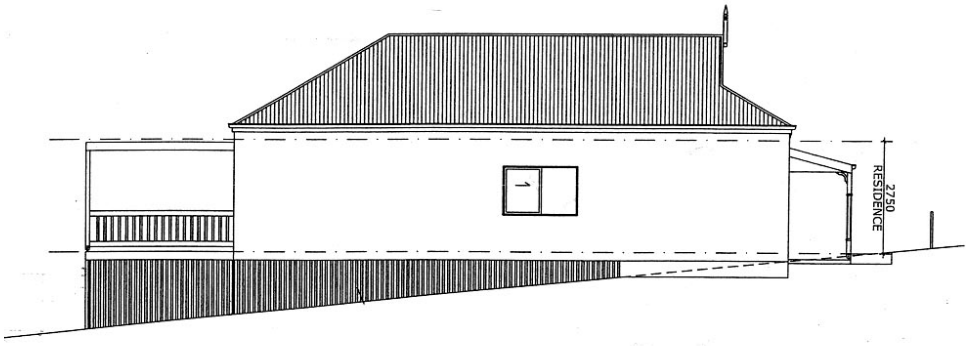
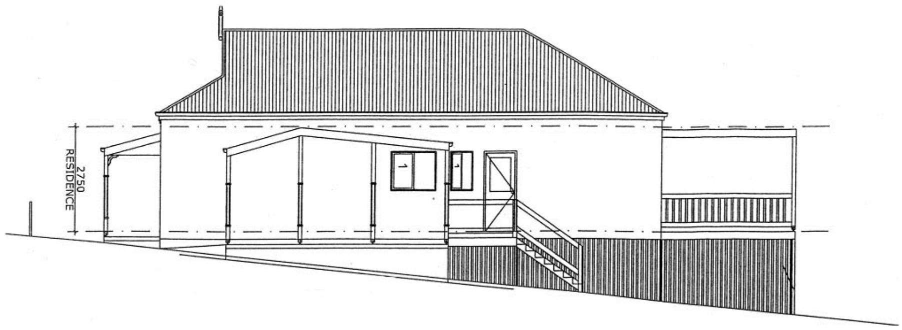


Figure 8.74 Elevation 3 - north

Figure 8.75 Elevation 4 - east



Constructions

Walls

External walls are weatherboard with above standard bulk insulation to R1.7.

Flooring

Flooring was assumed to be hardwood flooring with carpet or tiles throughout.

Table 8.35 Conditioned floor areas

BERS	Floor area (m²)	AccuRate	Floor area (m²)
Living 1	45.8	Living/kitchen	45.53
Sleeping 1	24.0	Bedroom 1	10.98
		Bedroom 2	12.16
Sleeping 2	10.5	Bedroom 3	12.16
Conditioned floor area	80.3 (80 %)	Conditioned floor area	80.80 (80 %)
Service 1	12.00	Laundry/WC	8.23
Service 2	9.00	Bathroom	12.44
Unconditioned floor area	21.00	Unconditioned floor area	20.67
Total internal floor area	101.3	Total internal floor area	101.15

The total conditioned floor areas and the rooms comprising that total are similar for both programs, enabling direct comparisons between the programs.

Assessing energy efficiency and the impact of increased external shielding

This case study highlights the anomalies created by the treatment of the under floor area. The above dwelling elevations show the under floor area to be enclosed with battens and there are problems with modelling such spaces in the thermal programs.

In BERS, the dwelling was initially modelled as a single storey, high set dwelling with an open under floor area. It is not known what assumptions BERS makes for such areas.

In AccuRate, the dwelling was initially modelled with a sub-floor zone, set as 'open'. The results of these simulations follow:

Table 8.36 Thermal program comparisons with sub-floor zone in AccuRate

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	60.7	125.5	186.3	
BERS Under floor open	131.8	78.9	210.7	1.5
AccuRate Open sub-floor Moderate shielding	61.9	98.4	160.3	
AccuRate Open sub-floor Heavy shielding	61.7	109.1	170.8	

The above table shows the expected drop in cooling between NatHERS and AccuRate, with the cooling and total energy loads increasing as the external shielding increases.

The BERS heating and cooling loads have not been transposed and it is the variation in cooling loads between the programs that is the issue.

In AccuRate, the sub-floor zone was removed and the zone below the dwelling set to outdoor air. The results of these simulations follow.

Table 8.37 Thermal program comparisons with open air under floor in AccuRate

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	157.6	280.5	309.1	
BERS Under floor open	131.8	78.9	210.7	1.5
AccuRate No sub floor zone Open air below	158.6	119.3	278.0	

The heating, cooling and annual total loads in BERS now appear in context and the treatment of the underfloor area has been identified as one cause of the variation in the energy loads between the programs.

One final variation was trialed to highlight the significance of this issue in both programs. The under floor area was changed from open to enclosed in BERS, which is another possible interpretation of the impact of closely spaced battens. The results of all these simulations appear in the following table:

Table 8.38 Case study 8 - program comparisons with open air under floor in AccuRate

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	157.6	280.5	309.1	
BERS Under floor open	131.8	78.9	210.7	1.5
BERS Under floor enclosed	86.8	67.4	154.2	2.5
AccuRate Open sub-floor Moderate shielding	61.9	98.4	160.3	
AccuRate No sub floor zone Open air below	158.6	119.3	278.0	

The performance of these spaces would seem to be somewhere the extremes of an enclosed sub-floor zone that has minimal openings for ventilation and the completely open under floor indicated by 'open air'. While these areas are subject to air transfers and are open to the effect of both hot and cold air, anecdotal evidence suggests that, for the most part these areas are shaded and cooler than the outside air in summer. A better understanding is needed of the ventilation of these battened sub-floor areas.

The following simulations have been run using the sub-floor setting.

Impact of orientation on energy efficiency

Figure 8.76 Dwelling orientation simulations starting from assumed north point

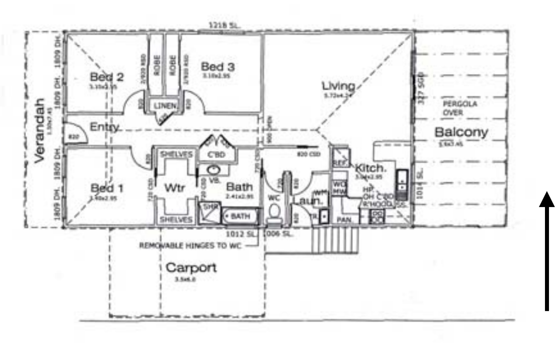


Table 8.39 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	53.8	95.4	149.3	
45	48.4	87.6	136.1	
90	50.9	97.8	148.7	
135	60.6	98.5	159.1	
180	59.4	88.6	148.1	
225	61.9	100.0	161.9	
270	58.2	105.9	164.1	
315	58.4	104.3	162.7	
Range	13.5	17.3	23.0 (20 %)	

Thermal program issues arising from case study 8

- The treatment of the underfloor area has been identified as one cause of the variation between the programs.
- A better understanding is needed of the ventilation of these battened sub-floor areas.

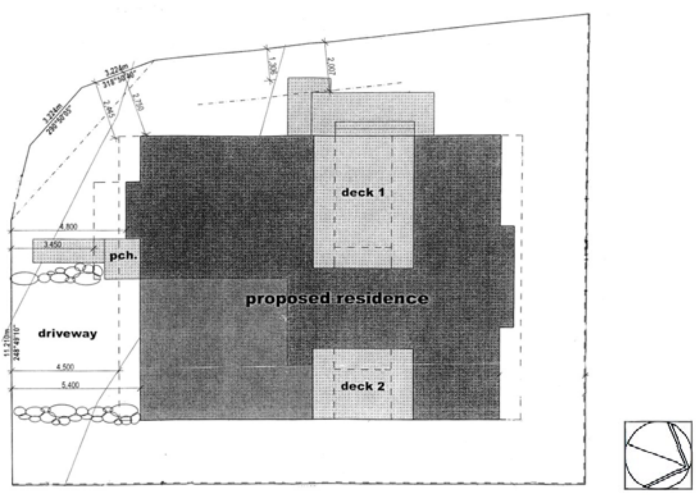
Criteria for possible future tools arising from case study 8

Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling has resulted in a decrease of 14 % in the annual total load between NatHERS and AccuRate.
- Using the open sub-floor setting in AccuRate, altering the orientation resulted in an increase in the annual total load of 20 % above the optimum level to a total of 164.1 MJ/m²/annum for the worst orientation;
- The optimum orientation was outside the range predicted by the SEDA lot-rating tool. There were a range of orientations that provided the worst, or close to the worst energy loads, and the overall range in terms of impact on energy loads is significant;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 6 % in the annual total energy load to a total of 170 MJ/m²/annum;
- The impact of increased external shielding is similar in total to that achieved by altering the orientation alone.

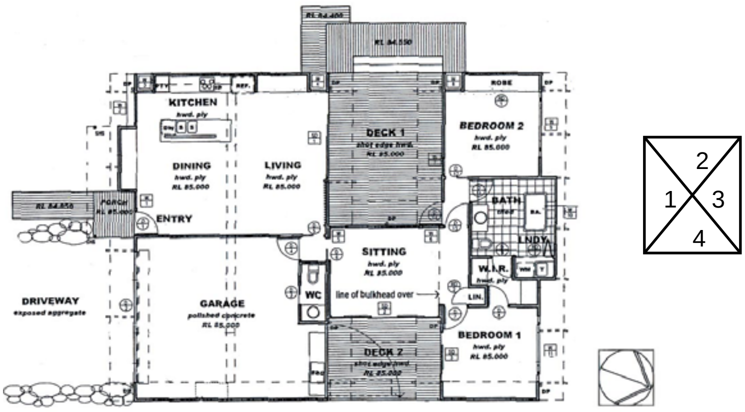
D.4.4 Case study 9 - pre fabricated dwelling

Figure 8.77 Site plan



- Lot 402m² - small (under 450m²);
- Lot rating – 5 Star.

Figure 8.78 Floor Plan



- Small, 140m², single storey;
- Elevated, lightweight construction, metal roof 11º pitch;
- 2 bedroom, 1 pedestal.

Figure 8.79 Elevation 1 – south

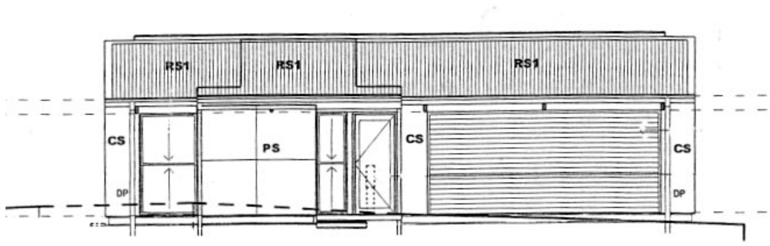


Figure 8.80 Elevation 2 – west

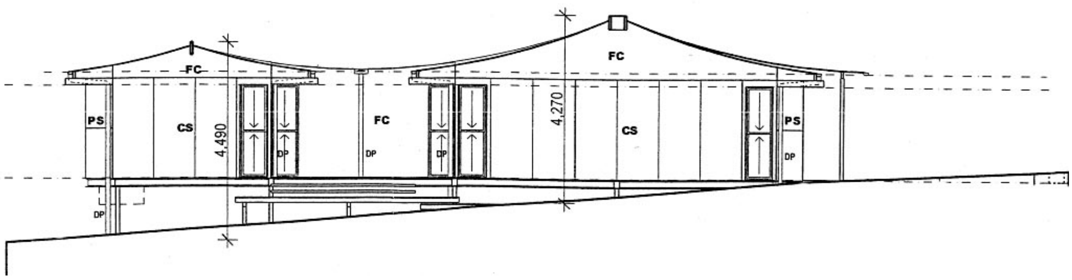


Figure 8.81 Elevation 3 - north

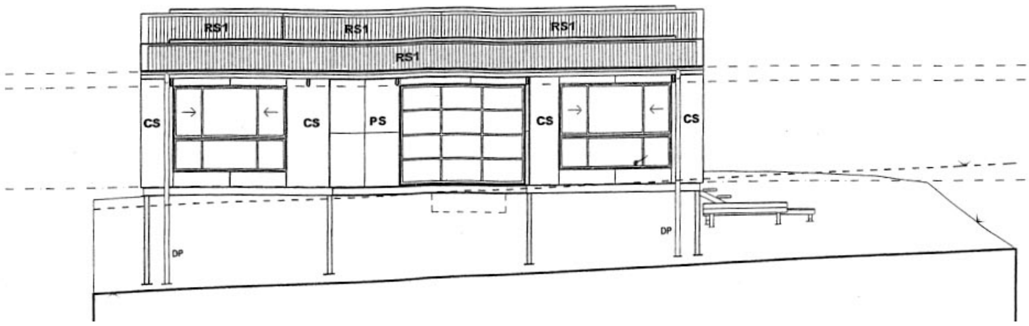
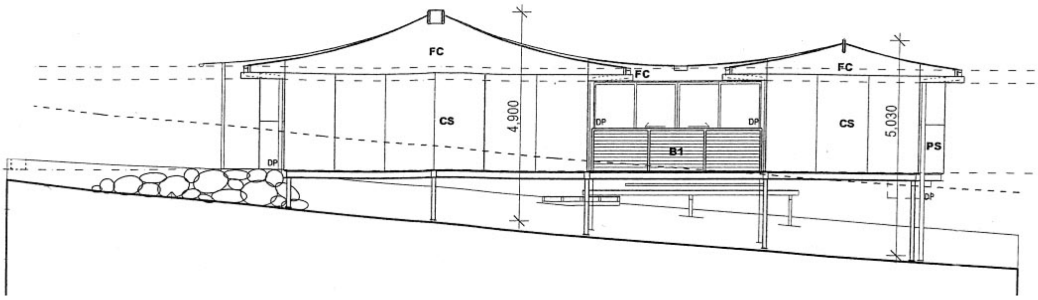


Figure 8.82 Elevation 4 - east



Constructions

Walls

External walls are weatherboard with above standard bulk insulation to R1.7. The sub-floor walls are battens and this material has been discussed previously in this report. The degree of openness is set to open in both programs.

Flooring

The flooring selected is hardwood ply over plasterboard for the living areas, ceramic tiles in the bathrooms and carpet in the bedrooms. This differs from the case study 8, which is hardwood flooring with carpet or tiles throughout.

Roof window

The detail of this roof window was not known, assumed to be 4mm clear. This may be a conservative selection.

Table 8.40 Comparison of conditioned floor areas

BERS	Floor area (m²)	AccuRate	Floor area (m²)
Living 1	42.0	Entry/living/kitchen/family	42.48
Living 2	14.0	Unconditioned in AccuRate	
Sleeping 1	14.0	Bedroom 1	12.24
Unconditioned in BERS		Bedroom 2	13.68
Conditioned floor area	70.0 (49 %)	Conditioned floor area	68.42 (48 %)
		Sitting	19.78
Bedroom 2	12.3		
Service 1	15.8	Laundry/bathroom	14.66
Service 2	42.00	Garage	43.20
Total internal floor area	140.64	Total internal floor area	146.06

The conditioned floor areas are similar, however, as in other case studies; the rooms comprising that total vary. In BERS, the two living zones mean that only one bedroom can be conditioned. In AccuRate, both bedrooms are conditioned, as is one of the living areas.

Assessing energy efficiency and the impact of increased external shielding

In BERS, the dwelling was modelled as single storey, high set with open under floor space. In AccuRate, the dwelling was modelled with a sub-floor area, set as 'open'. The results of these simulations follow:

Table 8.41 Thermal program comparisons

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	56.0	213.4	268.8	
BERS Terrain suburban	75.3	184.7	260.0	
AccuRate Moderate shielding	56.9	113.1	169.9	
AccuRate Heavy shielding	56.8	132.6	189.4	

The above table shows the expected drop in cooling between NatHERS, BERS and AccuRate, with the cooling and total energy loads increasing in AccuRate as the external shielding increases.

- However the sub-floor issue remains. This is an elevated dwelling and is expected to have a battened sub-floor area.
- At present the AccuRate modelling will be benefiting from the sub-floor selection.
- Both programs will be affected by bias toward larger dwellings, and away from smaller dwellings;

Impact of orientation on energy efficiency

Figure 8.83 Dwelling orientation simulations starting from assumed north point

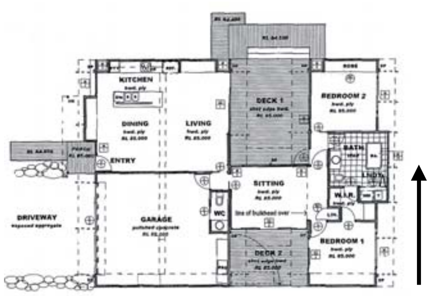


Figure 8.84 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	49.4	148.1	197.5	
45	57.0	124.0	180.9	
90	57.4	111.7	169.1	
135	58.7	118.1	176.8	
180	61.2	125.6	186.7	
225	69.1	124.5	193.6	
270	63.1	118.4	181.4	
315	50.0	140.0	190.0	
Range	19.7	36.4	28.4 (17 %)	

Thermal program issues arising from case study 9

- A better understanding is needed of the ventilation of battened sub-floor areas.

Criteria for future tools emerging from case study 9

Combining sub-division and dwelling performance, the main findings from this case study were:

- Improved ventilation modelling has resulted in a decrease of 37 % in the annual total load between NatHERS and AccuRate.
- In AccuRate, altering the orientation resulted in an increase in the annual total load of 17 % above the optimum level to a total of 197.5 MJ/m²/annum for the worst orientation;
- The optimum orientation was in range predicted by the SEDA lot-rating tool. The worst orientation was outside the range predicted;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 12 % to a total of 189.4 MJ/m²/annum;
- For this dwelling, the impact of altering the orientation is similar in range and total to the impact of increasing the external shielding.

D.5 Case Studies 10 to 16 - Attached Dwellings

The aim of this section of the project is to examine the adequacy of current design options in the context of an emerging energy code for medium and high-density dwellings. For the purpose of this project, medium density is defined as two to three storey developments, while high density is defined as being four stories and over. These are common usage terms and may not correspond with definitions used by local authorities.

The methodology for this examination is as follows:

- To examine a range of one, two and three bedroom medium and high density dwellings and compare the heating, cooling and annual total loads achieved in NatHERS with those achieved in AccuRate;
- To compare the annual total load with those estimated by the AGO;
- To examine the impact of orientation on energy efficiency; and
- Examine the impact of increased external shielding on energy efficiency for the medium density dwellings was increased in AccuRate from moderate (suburban) to heavy (inner urban). Heavy shielding was assumed for the high-density dwellings.

The aim is not to determine which program is most appropriate as BERS was designed to the annual thermal performance of houses. At the time it was developed, there was no requirement for performance ratings on apartment dwellings. As a result, BERS was not been used for this portion of the study.

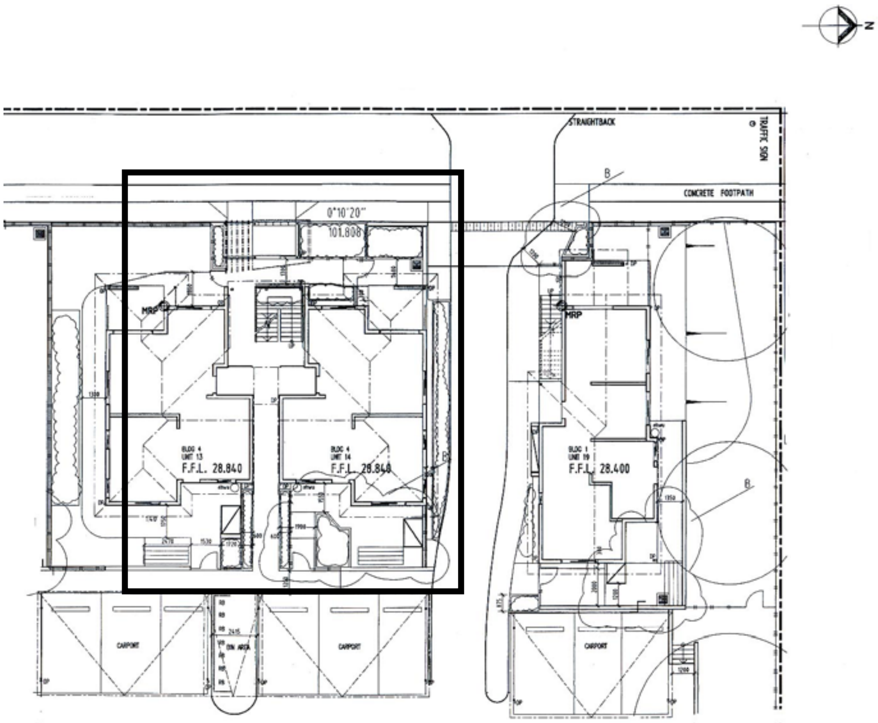
The plans provided by the Project Partners referred to apartment developments located throughout Queensland. To eliminate variations based on differing climatic conditions, all apartment dwellings were modelled as if they were located in an inner urban environment, specifically in Kelvin Grove, Brisbane.

D.5.1 Case study 10 - medium density dwelling

Case study selection

This apartment development consisted of twenty, one bedroom apartments. The apartment selected for analysis is a mid level apartment located in the centre of the complex. The apartments at this level are separated by stairwells

Figure 8.85 Site plan



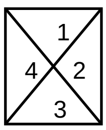


Figure 8.86 Elevation 1 - west

Figure 8.87 Elevation 2 - north

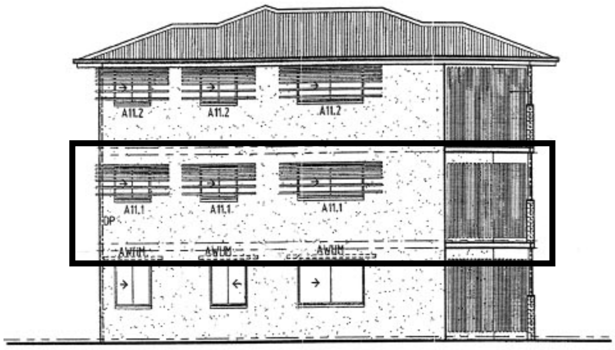


Figure 8.88 Elevation 3 - east

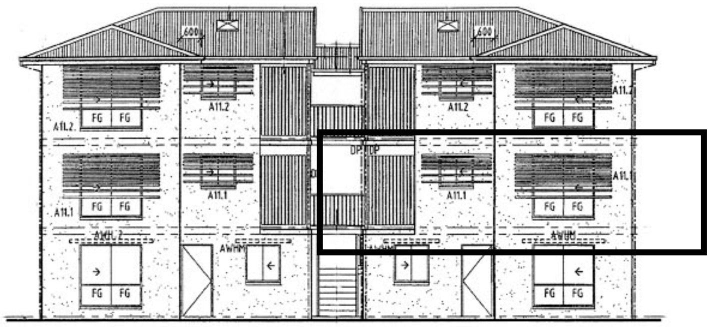


Figure 8.89 Elevation 4 – south - section through apartment block

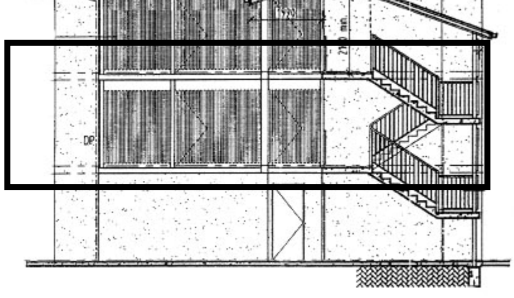


Figure 8.90 Section through selected apartment

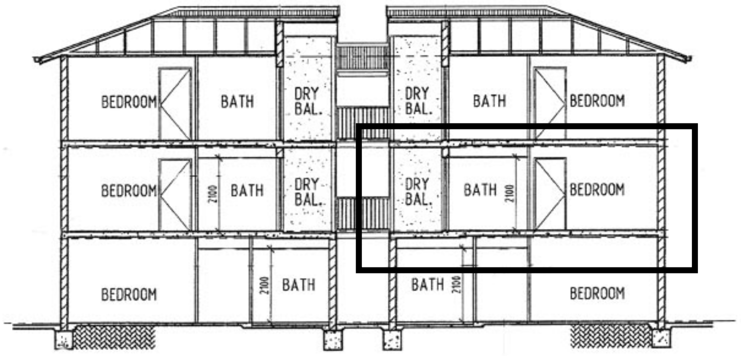
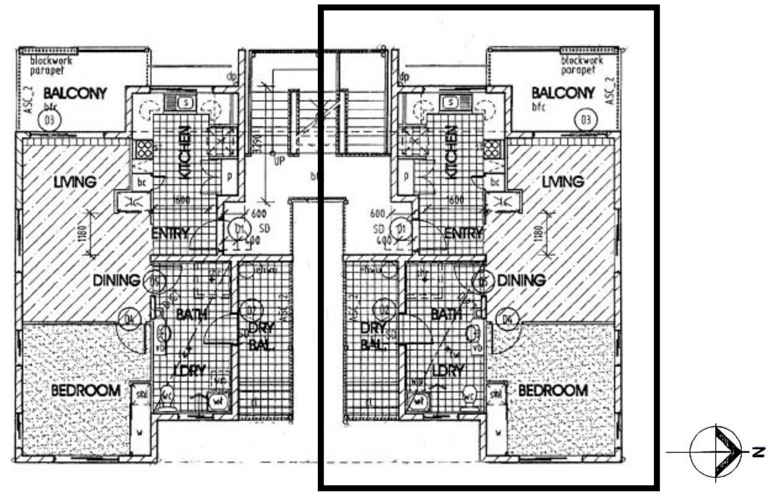


Figure 8.91 Floor Plan showing selected apartment



Constructions

Walls

The external walls are assumed to be concrete block and plasterboard and with no wall insulation. Holland blinds and medium colours assumed throughout.

Floors

The flooring is assumed to be 100mm concrete with either carpet or tiles.

In AccuRate the zone under the floor can be selected as either ‘open air’ or ‘neighbour’.

Ceiling

The ceiling is assumed to be 13mm plasterboard with no insulation. It was assumed that the top-level apartments might be insulated; but no top-level apartments were selected to be included in this study. In AccuRate, the zone above the ceiling is nominated as ‘neighbour’.

Table 8.42 Conditioned floor area selected apartment

AccuRate	Floor area (m^2)
Kitchen	15.93
Living	16.77
Bedroom	14.84
Conditioned floor area	47.5m^2 (82 %)
Laundry/Bathroom	9.89
Total internal floor area	57.43

Assessing energy efficiency and the impact of increased external shielding

Table 8.43 Thermal program comparisons and the impact of increased external shielding

Thermal program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	36.5	88.1	124.6	
Moderate – suburban housing	36.9	53.7	90.6	
Heavy - inner city housing	36.9	62.2	99.1	

In AccuRate, the heating load does not alter between the simulations. However, after the initial decrease in cooling and annual total loads, these both increase by approximately 9 % as surrounding obstructions reduce natural ventilation.

Impact of orientation on energy efficiency

Medium density apartments are common in inner urban areas in SEQ, but are less common in the CBD so heavy shielding was selected as the default for the medium density orientation simulations. The results are summarised in the following table:

Table 8.44 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	39.5	53.6	93.0	
45	37.7	61.5	99.2	
90	41.9	59.0	100.9	
135	46.0	57.7	103.6	
180	42.1	56.7	98.8	
225	39.6	57.5	97.1	
270	36.9	62.2	99.1	
315	38.5	58.6	97.1	
Range	9.1	8.6	10.6 (9 %)	

Findings

- Altering the orientation in a suburban setting results in a range of 9 % in the annual total load to a total of 103.6 MJ/m²/annum. This is due to increases in both the heating and cooling loads;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 9 % to a total of 99.1 MJ/m²/annum;
- For this dwelling, the impact of altering the orientation is similar in range and total to the impact of increasing the external shielding.
- The overall total energy loads are low when compared to the detached dwellings.

D.5.2 Case study 11 - medium density dwelling

Case study selection

The development consists of 5 x 2 and18 x 3 bedroom apartments located in two buildings. The selected apartments have approximately twice the internal floor space of the previous case study.

Figure 8.92 Site plan

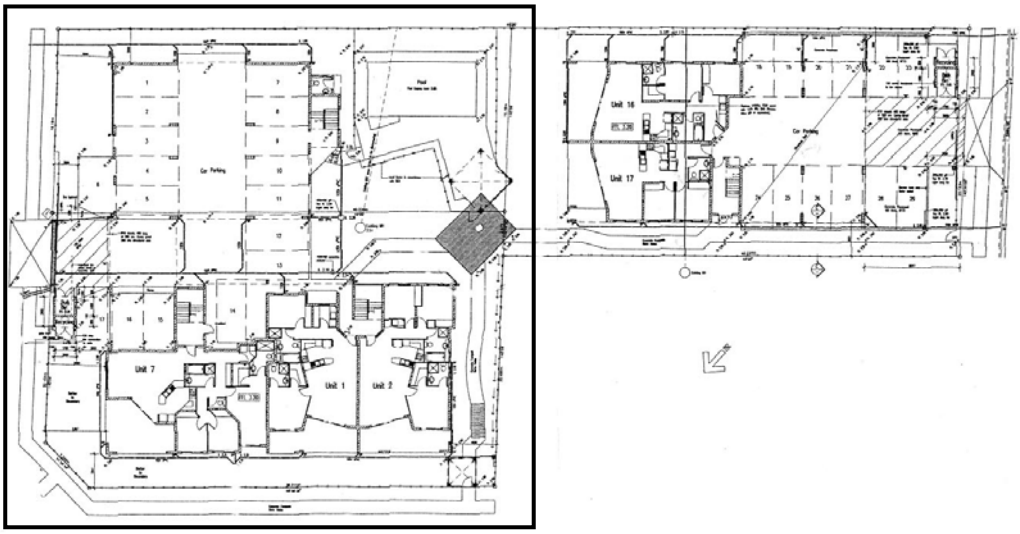


Figure 8.93 Floor plan level 2 showing selected apartments

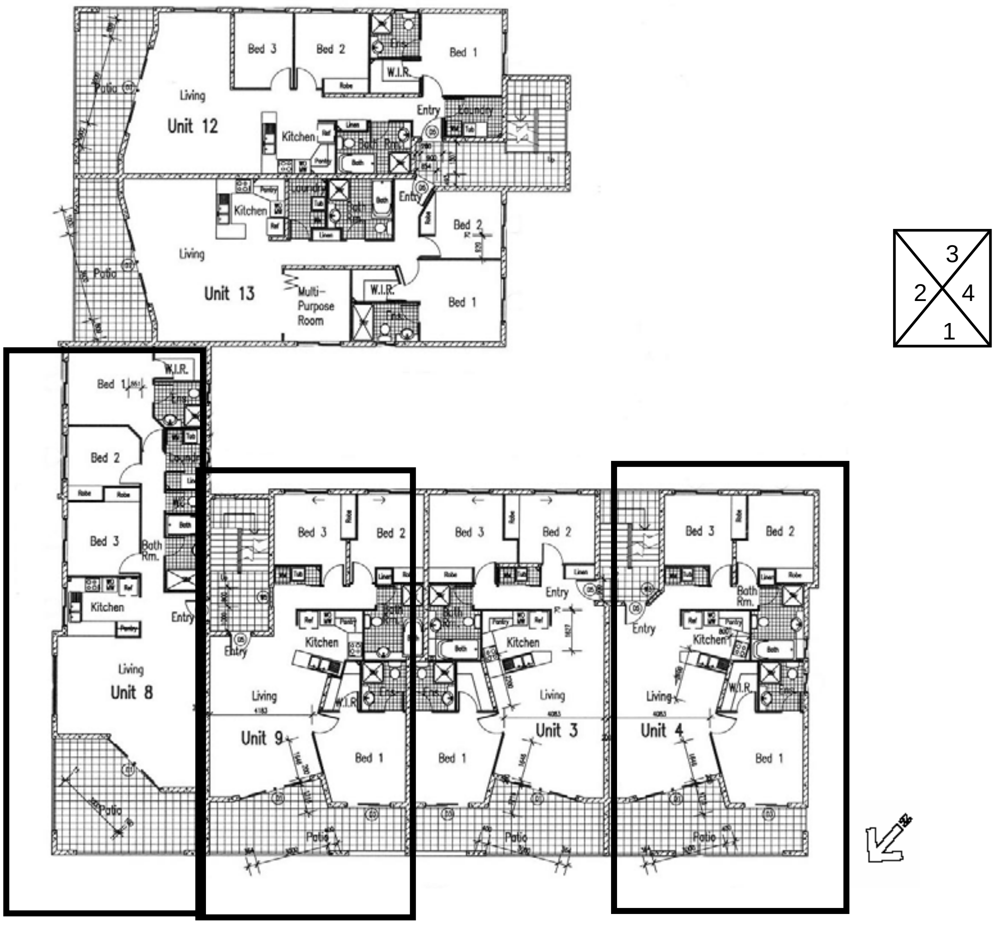


Figure 8.94 Elevation 1 – north

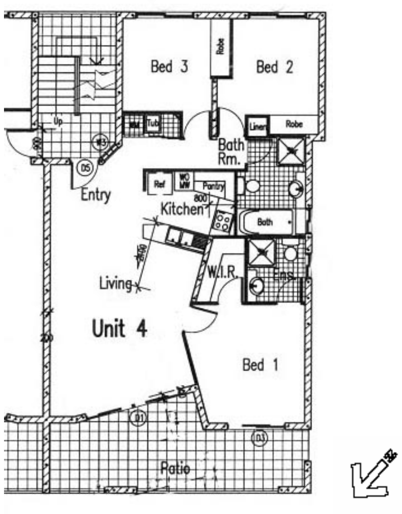
Figure 8.95 Elevation 2 – east

Figure 8.96 Elevation 3 – south

Figure 8.97 Elevation 4 – west

There are 5 x 3 bedroom apartments at this level. The 6th apartment has a multi-purpose room with a bi-fold door that could be used as a 3rd bedroom. Alternately, any of the bedrooms could be used as SOHO's.

Figure 8.98 Floor plan case study apartment



Constructions

There are no unusual constructions associated with this dwelling. This apartment has three external walls and shares a common wall with the neighbouring apartment. It also has neighbouring apartments both below and above.

Table 8.45 Conditioned floor space case study apartment

AccuRate	Floor area (m²)
Kitchen/living	44.10
Bedroom 1	15.74
Bedroom 2	12.92
Bedroom 3	11.78
Conditioned floor area	84.5m² (83 %)
Bathroom	9.38
Ensuite	7.17
Total internal floor area	101.09

The total internal floor area and the conditioned floor area of this apartment are similar to case study 3, the small brick veneer on slab, detached dwelling.

Assessing energy efficiency and the impact of increased external shielding

Table 8.46 Thermal program comparisons and the impact of increased external shielding

Thermal Program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	16.5	54.6	71.1	
AccuRate Moderate shielding	16.5	43.8	60.4	
AccuRate Heavy shielding	16.5	51.5	67.6	

AccuRate records a reduction in cooling load that reduces as the degree of shielding increases from moderate to heavy, reducing natural ventilation, but the overall totals are comparatively small when compared to the detached dwelling energy consumptions.

Impact of orientation on energy efficiency

Table 8.47 Impact of orientation on energy efficiency

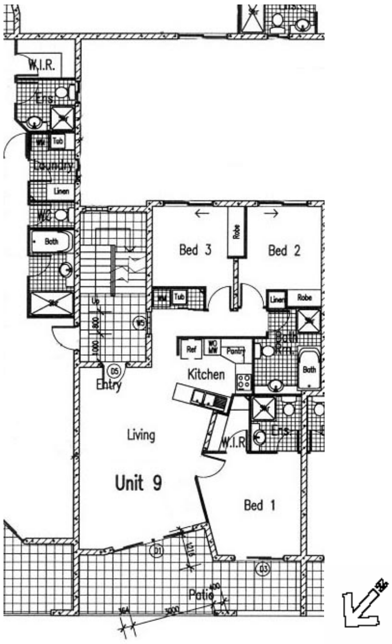
Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	13.9	55.6	69.6	
45	17.1	53.8	70.6	
90	17.6	55.8	73.4	
135	16.7	50.6	67.3	
180	12.7	46.9	59.6	
225	9.0	55.1	64.1	
270	7.4	58.7	66.1	
315	12.1	64.1	76.2	
Range	10.2	17.2	16.6 (27 %)	

Findings

- Altering the orientation results in a range of 27 % in the annual total load to a top of 76.2 MJ/m²/annum. This is due to increases in both the heating and cooling loads;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 11 % to a total of 67.6 MJ/m²/annum;
- For this dwelling, the impact of altering the orientation is similar in range and total to the impact of increasing the external shielding.
- These findings need to be viewed in context, as while the increases appear to be large, the overall totals are comparatively small when compared to the detached dwelling energy consumptions.
- When both are modelled with the same degree (heavy) of external shielding, this apartment is 46 % more efficient than detached dwelling, case study 3.

D.5.3 Case study 12

Figure 8.99 Floor plan case study apartment



This apartment has the same internal layout as the preceding case study 11, but is a central unit with two external walls and two common walls. It is also shielded by an apartment above and part of another apartment below. The rear bedrooms are located over an entry courtyard, which will reduce the thermal insulation.

Assessing energy efficiency and the impact of increased external shielding

For the purposes of this study the garage areas under the apartments have been selected as 'open air'

Table 8.48 Thermal program comparisons and the impact of increased external shielding

Thermal Program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	18.4	47.2	65.6	
AccuRate Moderate shielding	18.4	37.0	55.4	
AccuRate Heavy shielding	18.4	42.3	60.8	

Case study 12 follows a similar pattern to case study 11 with a drop in both the cooling and annual totals compared with NatHERS, followed by an increase in cooling as this ventilation is blocked by external elements such as neighbouring apartment blocks. This apartment uses marginally less energy (5-7 MJ/m²/annum) and it is assumed that the thermal insulation of the adjoining units compensates for the reduction for the portion of the unit over the garage.

Impact of orientation on energy efficiency

Table 8.49 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	16.1	41.0	57.1	
45	16.4	43.8	60.3	
90	17.2	48.7	65.9	
135	18.4	42.5	60.9	
180	18.0	36.1	54.0	
225	17.1	41.7	58.9	
270	15.5	49.4	65.5	
315	18.0	49.0	67.1	
Range	2.9	13.5	10.0 (17 %)	

Findings

- Altering the orientation in a suburban setting results in a range of 17 % in the annual total load to a total of 67.1 MJ/m²/annum. This is predominantly due to an increase in the cooling load;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase of 9 % to a total of 60.6 MJ/m²/annum;
- For this dwelling, the impact of altering the orientation is similar in range and total to the impact of increasing the external shielding.
- These findings need to be viewed in context, as while the increases appear to be large, the overall totals are comparatively small when compared to the detached dwelling energy consumptions.
- When both are modelled with the same degree (heavy) of external shielding, this apartment is 52 % more efficient than detached dwelling, case study 3.

D.5.4 Case study 13 - medium density dwelling

Figure 8.100 Floor plan case study apartment

This apartment has a different internal layout but has a similar conditioned floor area to the preceding case studies.

Table 8.50 Conditioned floor space case study apartment

Zone	Floor area (m²)
Kitchen/Living	54.07
Bedroom 1	14.01
Bedroom 2	8.86
Bedroom 3	10.88
Conditioned floor area	87.82m² (80 %)
Laundry/Bathroom	15.16
Ensuite	7.83
Unconditioned floor area	22.99
Total internal floor area	110.88

Assessing energy efficiency and the impact of increased external shielding

This apartment has three external walls and two common walls with an apartment above it and another below the living area. The majority of this apartment is located over the garage area, which is not a conditioned space. It is expected that the heating and cooling loads will increase when compared to previous apartments.

Table 8.51 Thermal program comparisons and the impact of increased external shielding

Thermal Program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	40.3	72.9	113.2	
AccuRate Moderate shielding	40.3	67.3	107.9	
AccuRate Heavy shielding	40.3	76.1	116.4	

The heating load has more than doubled and the cooling load has increased by approximately 80 % compared to case study 12. In this instance, the impact of heavy shielding negates natural ventilation.

Impact of orientation on energy efficiency

Table 8.52 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	59.4	83.5	143.0	
45	50.5	75.5	126.0	
90	39.6	68.8	108.3	
135	39.8	75.5	115.3	
180	46.7	77.5	124.2	
225	64.5	66.7	131.2	
270	70.4	55.5	125.9	
315	69.9	68.2	138.1	
Range	30.0	14.7	35.3 (32 %)	

The difference in orientation is more marked for this apartment than for the preceding case studies, with greater variations in heating, cooling and annual total loads. The overall totals now exceed those of case study 2, the small brick veneer on slab, detached dwelling. It would be illustrative at this point to model this apartment as if it were located above a neighbouring unit.

Impact of altering the neighbouring zoning on energy efficiency

Table 8.53 Impact of altering the neighbouring zoning on energy efficiency

Thermal Program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	29.4	68.1	97.6	
AccuRate Moderate shielding	29.4	59.5	88.9	
AccuRate Heavy shielding	29.4	70.7	100.1	

Changing the setting for the zone type for the area below the floor from ‘outdoor air’ to ‘neighbour’, results in a reduction of 16 MJ/m²/annum in the annual total load. Neither neighbour nor shielding assumptions appear to be disclosed on the ratings report at this stage.

Findings

- Altering the orientation with heavy shielding resulted in a range of 32 % in the annual total load to a total of 143 MJ/m²/annum for case study 11. This is due to increases in both heating and cooling loads, but mainly in the heating load;
- At the presented orientation, increasing the external shielding from suburban to heavy results in an increase to a total of 116 MJ/m²/annum;
- When both are modelled with the same degree (heavy) of external shielding, this apartment is only 7 % more efficient than detached dwelling, case study 3.
- For this medium density apartment, the impact of altering the orientation is significant.
- With heavy external shielding, at the worst orientations, the annual total for this apartment exceeds any achieved for case study 3.

D.6 Case Studies 14 to 16 - High-Density Dwellings

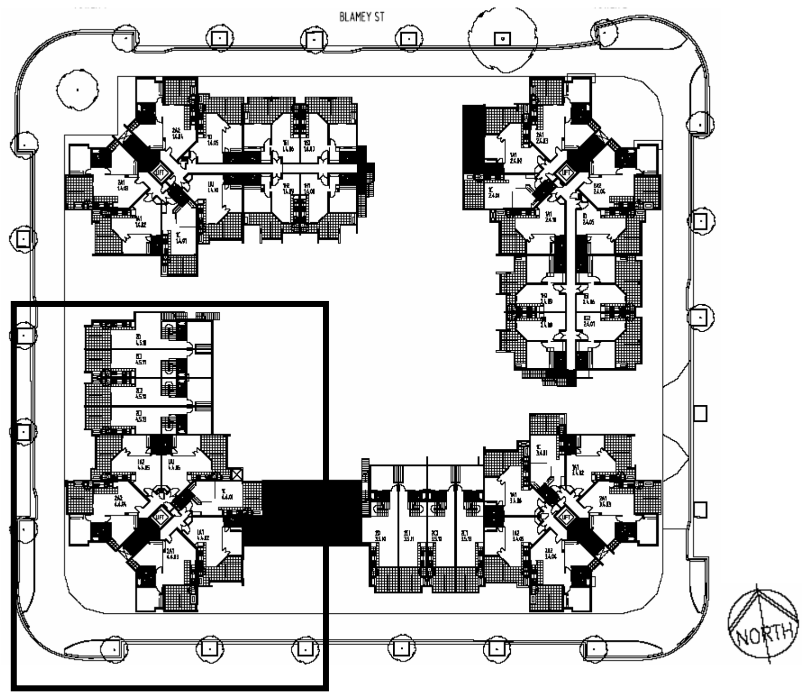
Introduction

For the purpose of this project, high density is defined as four or more storey developments, commonly serviced by a lift. This development consists of four tower blocks combining commercial and residential tenancies.

Case study selection

The apartments were selected based on the variation in the EERs that were completed by an external consultant in FirstRate. The EERs ranged from 1.5 to 5.0, with the rating of some apartments improving from 1.5 to 3.5 through the addition of external shading. Only the ratings were made available for this study.

Figure 8.101 Site plan showing selected tower



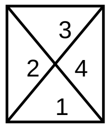


Figure 8.102 Floor plan tower 4, level 4 showing selected apartments

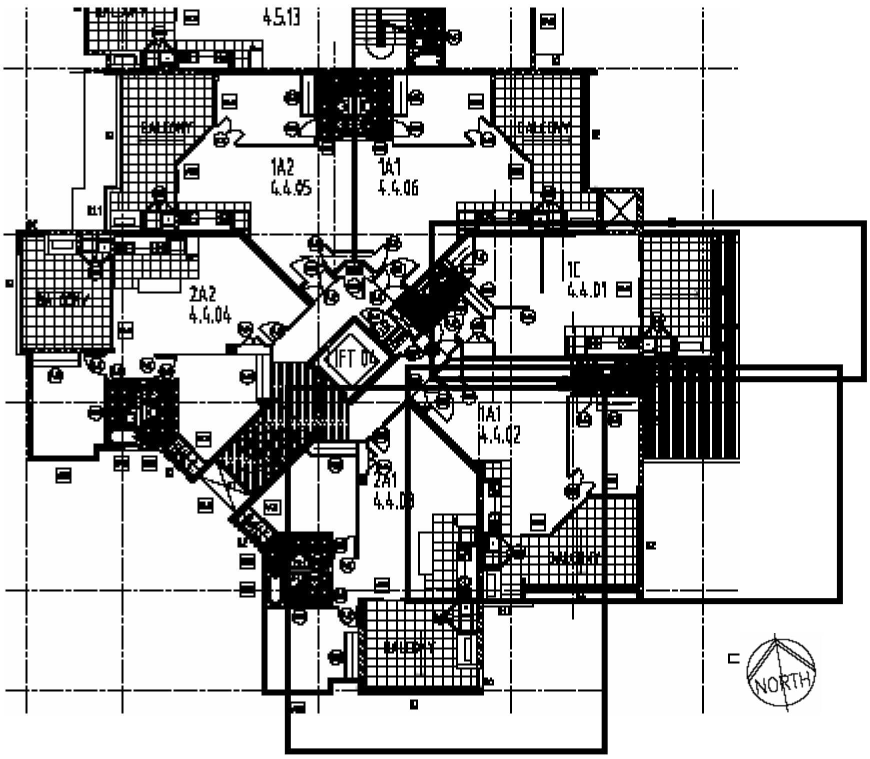


Figure 8.103 Elevation 1 - south

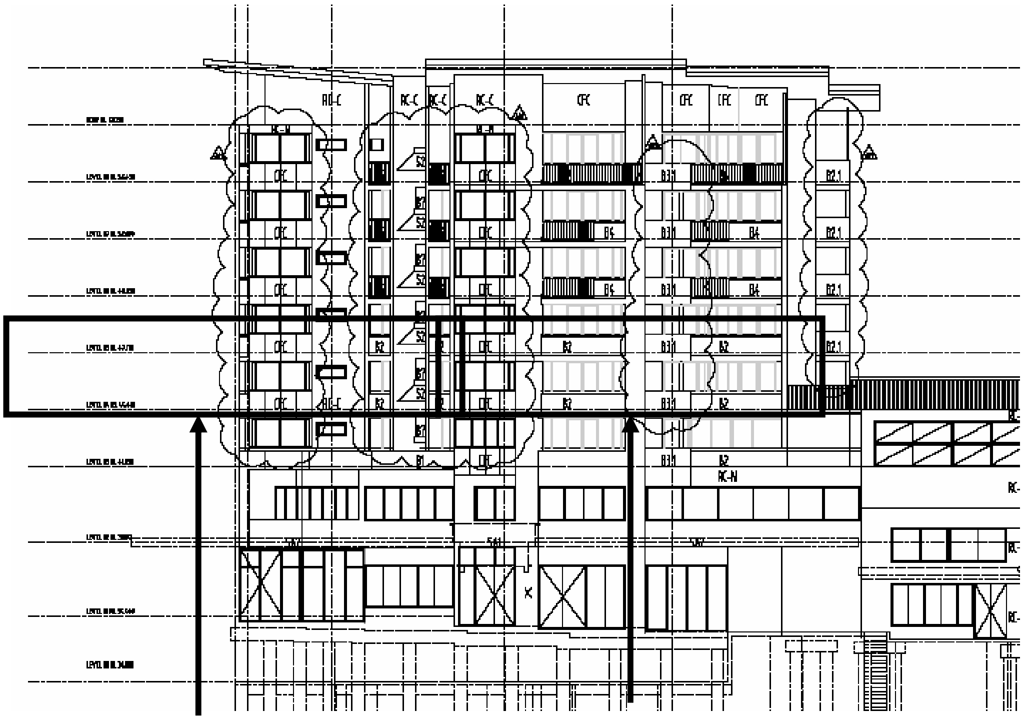


Figure 8.104 Elevation 2 - west

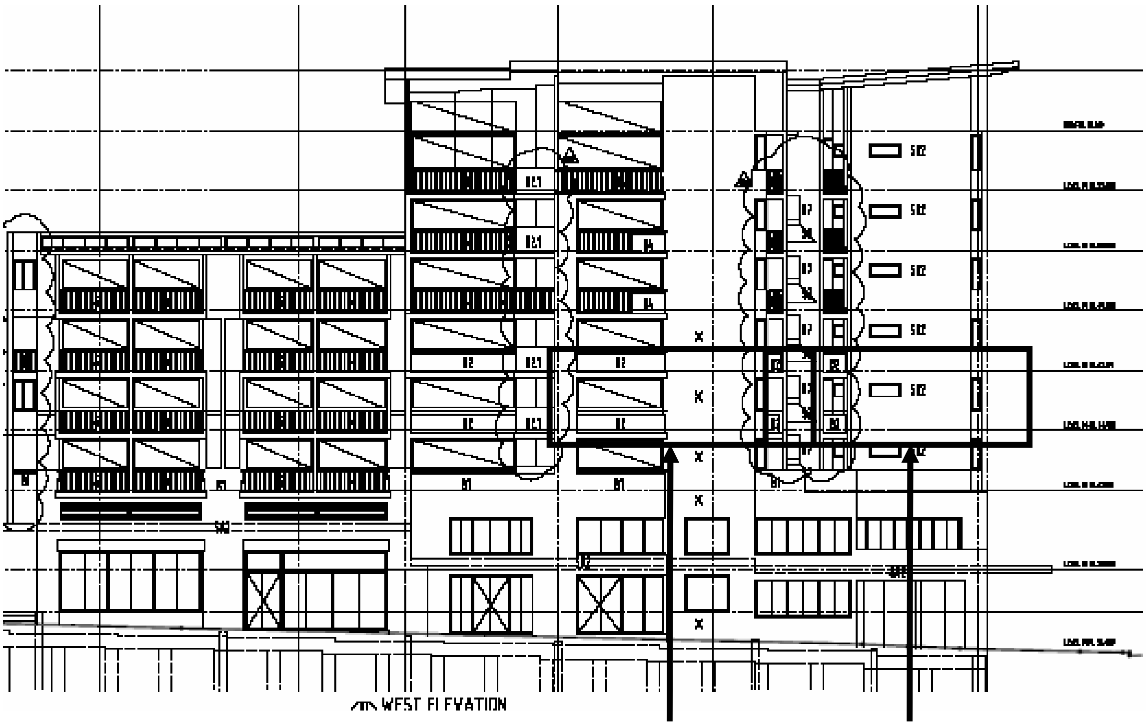


Figure 8.105 Elevation 3 - north

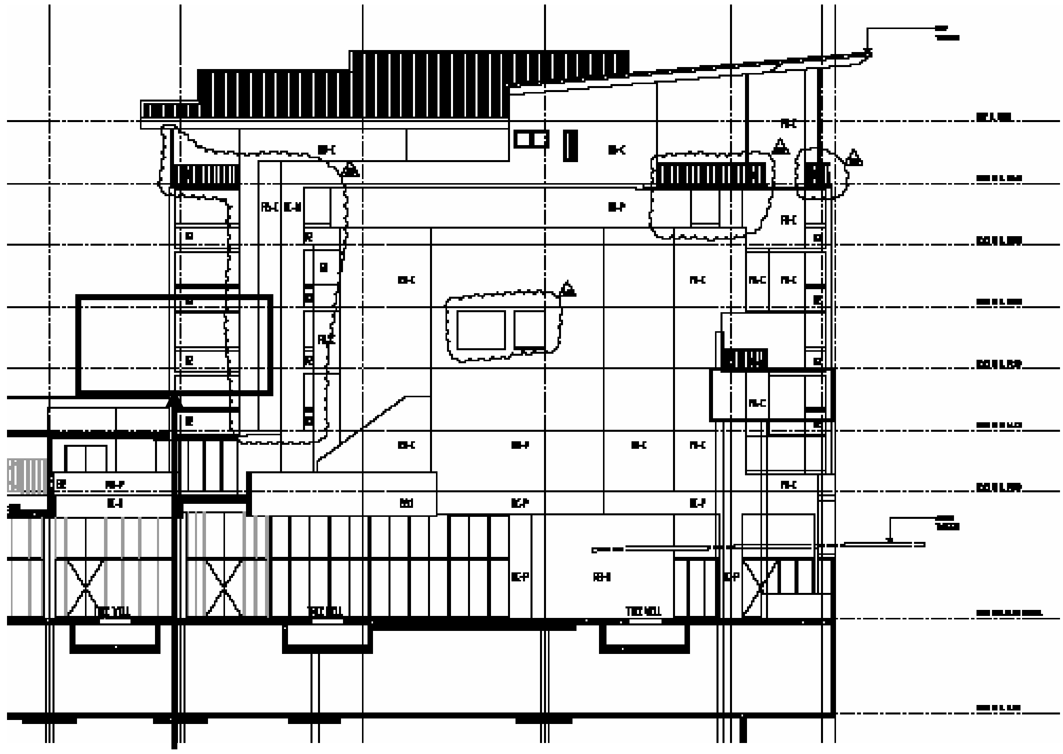
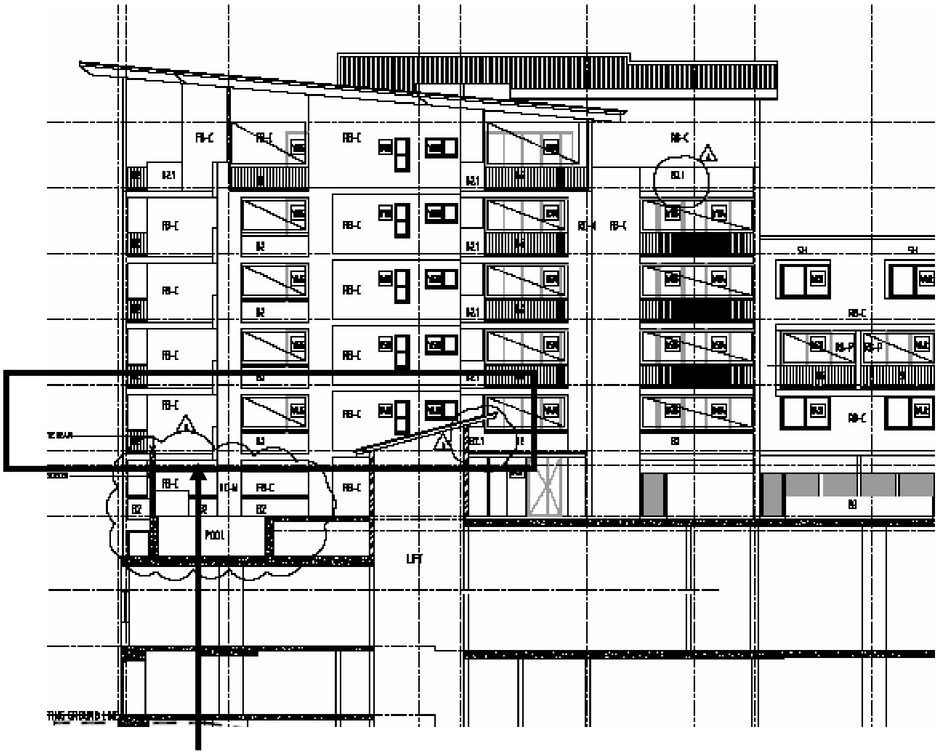


Figure 8.106 Elevation 4 - east



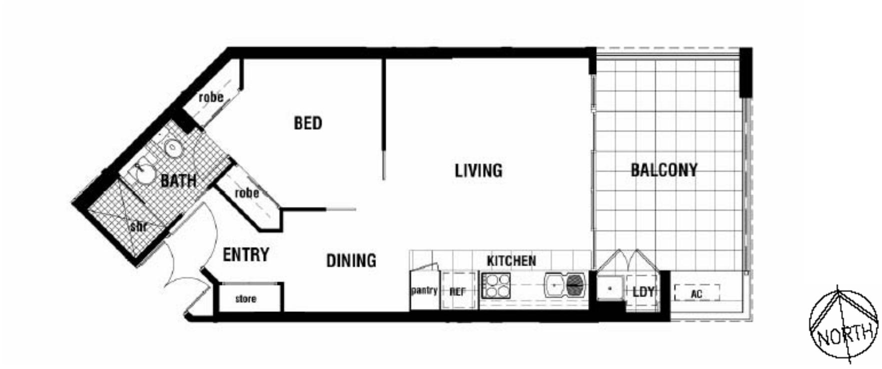
There are four, one bedroom and two, two bedroom apartments in the tower block at this level. The two bedroom apartments have the same internal layout and are either mirrored or oriented to suit the overall floor plan. As a result, only one was selected for modeling as the design variations will be captured in the orientation simulations. In the two bedroom apartments, either bedroom could be used as a SOHO. The one-bedroom apartments have different footprints and one of each was selected.

The main difference between these and the previous case study apartments is that these open a lift lobby. This area is likely to be cooler than the outside air, even if it is not a conditioned space, whereas the medium density apartments open to an entry foyer, which may be shaded, but is considered to be 'open air' for the purposes of thermal modelling.

The walls between the apartment and the lift foyer have been entered as internal walls in AccuRate to allow the adjoining zone to be set as 'neighbour'. AccuRate does not allow an opening in an internal wall that adjoins a neighbour and so the entry door cannot be considered. This was not expected to impact significantly on the thermal performance of the apartment as it is assumed that the entry door would not be left open for ventilation purposes.

D.6.1 Case study 14 – high density dwelling

Figure 8.107 Floor plan case study apartment



Constructions

There are no unusual constructions associated with these apartments.

Table 8.54 Conditioned floor space case study apartment

Zone	Floor area (m^2)
Zone 1 Kitchen/Living	33.0
Zone 2 Bedroom	9.6
Conditioned floor area	42.6 (89 %)
Zone 3 Bathroom	5.4
Unconditioned floor area	
Total internal floor area	48.0

This apartment has a similar floor area to case study 10, the 1 bedroom apartment.

Assessing energy efficiency and the impact of increased external shielding

Table 8.55 Thermal program comparisons and the impact of increased external shielding

Thermal Program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	6.8	72.9	79.8	
FirstRate			Not available	1.5 3.5
AccuRate Heavy shielding	6.8	78.0	84.9	

Possible explanations for why the cooling and total loads exceed NatHERS include:

- This small, enclosed apartment may be particularly susceptible to internal heatloads. The living area has been zoned as living/kitchen. The effect is to assign a heatload equivalent to cooking loads to the entire area. A similar increase was recorded when the zoning was changed from living/kitchen to kitchen.
- There is limited opportunity for cross flow ventilation.
- The designers have further acknowledged the lack of ventilation in this unit through the addition of double entry doors, allowing the occupier to open their entry door and leave double louvre doors closed, providing both security and ventilation.

- AccuRate does not allow an opening in an internal wall that adjoins a neighbour and so the entry door is not entered. It is not expected that thermal program will allow for this level of complexity in user operations.
- The designers added some external shading, increasing the FirstRate star rating from 1.5 to 3.5 stars. Details of this added shading were not available for this project.

Impact of orientation on energy efficiency

Table 8.56 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	4.0	77.7	81.7	
45	8.0	71.9	80.0	
90	8.0	68.8	77.6	
135	8.0	72.6	80.6	
180	6.0	85.2	91.3	
225	4.8	73.8	78.5	
270	6.8	69.3	76.1	
315	1.6	71.9	73.6	
Range	6.4	15.9	17.7 (24 %)	

Findings

- Altering the orientation with heavy shielding resulted in a range of 24 % in the annual total load to a total of 91.3 MJ/m²/annum. This is predominantly due to increases in the cooling loads.
- The overall total energy loads are small when compared to the detached dwellings.
- When both dwellings are modelled with the same degree (heavy) of external shielding, this apartment is 32 % more efficient than detached dwelling, case study 3.

D.6.2 Case study 15 – high density dwelling

Figure 8.108 Floor plan case study apartment

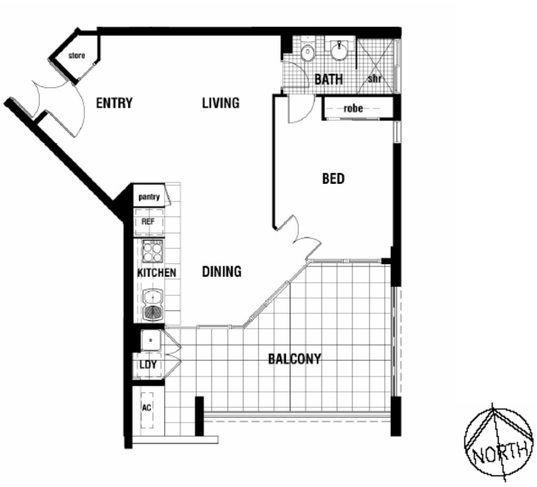


Table 8.57 Conditioned floor space case study apartment

Zone	Floor area (m²)
Zone 1 Kitchen/Living	37.0
Zone 3 Bedroom 1	13.0
Conditioned floor area	50.0 (91 %)
Zone 7 Bathroom	5.0
Total internal floor area	55.0

This apartment is also one bedroom, but is slightly larger and has a different footprint to case study 15.

Assessing energy efficiency and the impact of increased external shielding

Table 8.58 Thermal program comparisons and the impact of increased external shielding

Thermal Program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	19.1	72.8	91.8	
FirstRate			Not available	5.0
AccuRate Heavy shielding	19.1	64.3	83.4	

Simulation shows the expected reduction in the cooling and annual total loads.

Impact of orientation on energy efficiency

Table 8.59 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating
0	13.6	57.0	70.5	
45	17.4	60.3	78.6	
90	16.3	63.7	80.2	
135	13.8	62.8	76.6	
180	11.8	63.4	75.2	
225	5.8	55.4	61.2	
270	5.7	53.9	59.0	
315	8.2	54.3	62.5	
Range	11.6	8.3	17.4 (35 %)	

Findings

- Altering the orientation with heavy shielding resulted in a range of 17 % in the annual total load to a total of 91.3 MJ/m²/annum. This is predominantly due to increases in the cooling loads.
- The overall total energy loads are small when compared to the detached dwellings.
- When both dwellings are modelled with the same degree (heavy) of external shielding, this apartment is 33 % more efficient than detached dwelling, case study 3.

D.6.3 Case study 16 – high density dwelling

Figure 8.109 Floor plan case study apartment

Table 8.60 Conditioned floor space case study apartment

Zone	Floor area (m²)
Zone 1 Kitchen/Living	40.0
Zone 3 Bedroom 1	13.5
Zone 4 Bedroom 2	15.0
Conditioned floor area	68.5 (89 %)
Zone 7 Bathroom	8.4
Total internal floor area	77.0

Assessing energy efficiency and the impact of increased external shielding

Table 8.61 Thermal program comparisons and the impact of increased external shielding

Thermal Program	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
NatHERS Simple ventilation	21.2	55.5	76.7	
FirstRate				3.0
AccuRate Heavy shielding	21.2	56.5	77.7	

The total energy only drops below the NatHERS calculation when the external shielding is moderate – that is, typical of a suburban setting.

The degree of shielding is a judgement made by the rater and the importance of this decision is illustrated in the table above. This key assumption is not disclosed in the Rating statement.

Impact of orientation on energy efficiency

Table 8.62 Impact of orientation on energy efficiency

Orientation Degrees	Heating Load MJ/m²/annum	Cooling Load MJ/m²/annum	Annual Total Load MJ/m²/annum	Star Rating TBC
0	21.7	57.9	79.6	
45	19.2	64.7	83.9	
90	15.5	69.3	84.9	
135	14.1	62.1	76.1	
180	12.8	56.2	69.1	
225	10.8	60.6	71.4	
270	15.5	66.6	82.1	
315	22.4	55.2	77.5	
Range	10.9	14.1	13.5 (18 %)	

Findings

- Altering the orientation with heavy shielding resulted in a range of 18 % in the annual total load to a total of 84.9 MJ/m²/annum. This is due to increases in both the heating and cooling loads.
- At the presented orientation, increasing the external shielding from heavy to very heavy results in an increase of 19 % to a total of 92.4 MJ/m²/annum;
- The overall total energy loads are small when compared to the detached dwellings.
- When both dwellings are modelled with the same degree (heavy) of external shielding, this apartment is 38 % more efficient than detached dwelling, case study 3.

Appendix E - Project Deliverables

E.1 Project Reports

E.1.1 Barriers and Drivers to Sustainable Sub-division

Benchmarking the Practices, Perceptions and Design of Sustainable Subdivisions A report from Phase One on the barriers to energy efficient innovation, primarily because of disconnection between ‘housing technology’ and ‘sub-division technology’. Available on-line at http://internal.construction-innovation.info/

E.1.2 Refereed Publications

Ambrose, M., Mead, E., and Miller, A. (2004) Sustainable Suburbs – the Developers Challenge, Proc of CRC CI 1st Int. Conf. On Clients Driving Innovation, Gold Coast, Australia, 25-27th October. Available on-line at http://internal.construction-innovation.info/

ABSTRACT

As our cities expand, developers are transforming more and more land to create our ~~ther future~~ suburbs of the future. Developers and government bodies~~,~~ have a golden opportunity to design suburbs that are not only great places to live, but also are environmentally sensitive and sustainable. This is a unique opportunity, as significant changes after development are constrained by the configuration of the sub-division, and then by the construction of the dwellings.

This paper explores some of these issues by presenting initial findings from the CRC-CI, Sustainable Subdivisions Project. The Project examines the drivers and barriers that land developers face when trying to achieve sustainable subdivisions. This paper will review the results from a series of industry interviews and workshops and explore possible ways forward. In addition, the possible effect on the way future land sub-division is managed and planned as a result of recent changes in the energy efficiency provisions of the Building Code of Australia will be explored.

This paper highlights problems that both builders and land developers may face through poor sub-division design. Finally an innovative program being driven by a major land developer will be introduced. The program aims to deliver over 400 energy and water efficient homes through a series of compulsory and voluntary schemes that the developer is designing, funding and implementing. This program is the first large-scale development in Australia that demonstrates how developers can help achieve environmentally sensitive and sustainable suburbs of the future.

E.1.3 Refereed Publications (abstract accepted)

Ambrose, M., and Miller, A. (2004) How to Achieve Sustainability – Regulatory Challenges, Abstract accepted for the Conference on Sustainable Building South East Asia (SB04 Series) to be held in Kuala Lumpur, Malaysia, 11-13 April, 2005.

ABSTRACT

The importance of designing sustainable buildings is gaining greater acceptance worldwide. Evidence of this is how regulators are incorporating sustainable design principles into building regulations and requirements. The aim being to increase the number of sustainable buildings and move from a traditional voluntary compliance to one that is mandatory. However, developing regulations that actually achieve these aims can be a difficult exercise.

Several countries in South East Asia, such as Singapore and Malaysia, have performance based building regulations that are supplemented by prescriptive measures for achieving the desired performance. Australia too has similar building regulations and has had energy efficiency regulations within the Building Code of Australia for over a decade. This paper explores some of the difficulties and problems that Australian regulators have experienced with the performance-based method and the prescriptive or "deemed-to-comply" method and measures that have been taken to try and overcome these problems. These experiences act as a useful guide to all regulators considering the incorporation of sustainable design measures into their countries building regulations.

The paper also speculates on future environmental requirements being incorporated into regulations, including the possibility of non-residential buildings being required to meet minimum energy efficiency requirements, and the possible systems that would need to be in place before such requirements were included.

Finally, the paper looks at a possible way forward using direct assessment from electronic designs and introduces several software tools that are currently being developed that move towards achieving this goal.

Keywords: Sustainable buildings, Performance-based, Regulations, Energy efficiency, Assessment tools.

E.1.4 Refereed Publications (abstract accepted)

Miller, A. and Ambrose, M. (2004) Energy Efficient Multi Storey Residential Developments, Abstract accepted for the Conference on Sustainable Building South East Asia (SB04 Series) to be held in Kuala Lumpur, Malaysia, 11-13 April, 2005.

ABSTRACT

Worldwide, the current pattern of urban development is unsustainable and metropolitan planning and development strategies deliver poor environmental outcomes in relation to energy production. As a result, an increasing number of governments and private sector development companies are initiating projects that aim to deliver enhanced environmental outcomes rather than a 'business as usual' approach.

This paper will summarise the findings from a study that explored the link between building orientation and energy efficiencies in sub-tropical and tropical climates. The study used a new thermal modelling software tool developed by CSIRO that responds more accurately to residential heating and cooling energy performance in those climate zones. This software tool responds to industry criticisms regarding cold climate modelling systems that do not make sufficient allowance for natural ventilation. The study examined a range of low, medium and high-density dwelling types and the physical characteristics of the residential communities that they were built in. The study investigated the impact of orientation, insulation, ventilation and shading devices on energy efficiencies. This paper will examine the findings from the medium and high-density case study developments as this are relevant to residential developments in many South East Asian countries, such as Singapore, Hong Kong and Malaysia.

Finally, the paper will explore the potential benefits that medium and high-density residential developments have in the development of 'solar cities' and 'solar suburbs'.

Keywords: Sustainable buildings, energy efficiency, solar cities.

E.1.5 Industry Brochure

An industry brochure is to be developed.

E.1.6 Media Release

Ambrose, M. (2003) Solar Suburbs: lighting the future of housing development, Construction Innovation Update, August 2003, Issue 6.

E.1.7 Promotional Poster

Project poster was awarded 'Best Poster' at the CRC-CI Conference in October 2004.

E.1.8 Education

Classroom activity developed in conjunction with the CRC-CI.

Activity from CRC Construction Innovation and
CSIRO Manufacturing and Infrastructure Technology

Why is the classroom so hot?

Does your classroom get really hot over summer? Does the air conditioner have to be on all the time? What are the really hot classrooms to be in at school?

What you need:
Shoeboxes (without lids)
Colour card (with at least one black one and one white one)
Aluminium foil
Thermometers

What to do:
For each shoebox place a different piece of coloured card on top and using sticky tape stick one edge down to form a hinged lid.

In a shady outdoor area use one of the thermometers to measure the outside temperature (also check the daily paper to see what the maximum temperature for the day is expected to be).

Now place a thermometer in each box, close the lid and sticky tape down so it does not blow open and leave out in the sun for about one hour. If you only have one or two boxes or thermometers, then change the lids and repeat the experiment through the day.

Once the hour is up, open the box and record the temperature.

Now place a sheet of aluminium foil under the card lid of each box with the shiny side facing up. Close the box and again leave in the sun for about one hour. Once the hour is up, record the temperature.

What do you find?

Are you finding that the boxes with the dark colour lids are hotter than those with the light colour lids? Are you also finding that when the aluminium foil is added that the temperatures are lower?

What is going on?
Dark colours absorb more heat from the sun and this heat is then transferred to the box below making it hotter. Lighter colours reflect more heat and so don't heat up the box as much. When you add the aluminium foil this helps in reflecting even more of the heat away from the box, so temperatures are even lower.

E.1.9 Education

Classroom activity developed in conjunction with the CRC-CI.

"It's too hot in here!"

Does your classroom get really hot over summer? Does the air conditioner have to be on all the time (or do you wish you had one)? Which are the really hot classrooms at your school? Use this simple experiment to help understand why rooms heat up.

Materials

Two shoeboxes
One piece of black and one piece of white card (large enough to cover the top of box)
Aluminium foil
Two thermometers
Sticky tape
Plasticine (optional)
Two matchboxes

Method

Take one shoebox and use sticky tape to attach one edge of the black card to it to form a hinged lid that covers the top of the box. Do the same with the second box using white card. Alternatively, if the shoeboxes have a lid you could paint one lid black and the other white.

In a shady outdoor area use one of the thermometers to measure the outside temperature (also check the daily paper to see what the maximum temperature for the day is expected to be).<how should they best use this?>

Now place a thermometer in each box. For the best results, lie the thermometer on a matchbox so that it is not in contact with the bottom of the box. A small amount of tape or plasticine may help hold it in place. Close the lid and sticky tape it down so it does not blow open and leave out in the sun for 20 minutes.

After 20 minutes, open the boxes and record the temperatures.

Now place a sheet of aluminium foil under the card lid of each box with the shiny side facing up. Close the boxes and again leave in the sun for another 20 minutes. Then records the temperatures.

You may want to repeat this experiment at various times during the day and compare your results or perhaps use different coloured card and see what happens.

Results

Record your results in a table and describe in your own words what happened. Were temperatures in the boxes higher or lower then the temperature you recorded in the shade and/or higher or lower than the maximum forecast temperature?

Explanation

Use these words to complete the paragraph and diagram below (you may need to use some words more than once): transfer, lower, hotter, dark, reflect, more, lighter, absorb.

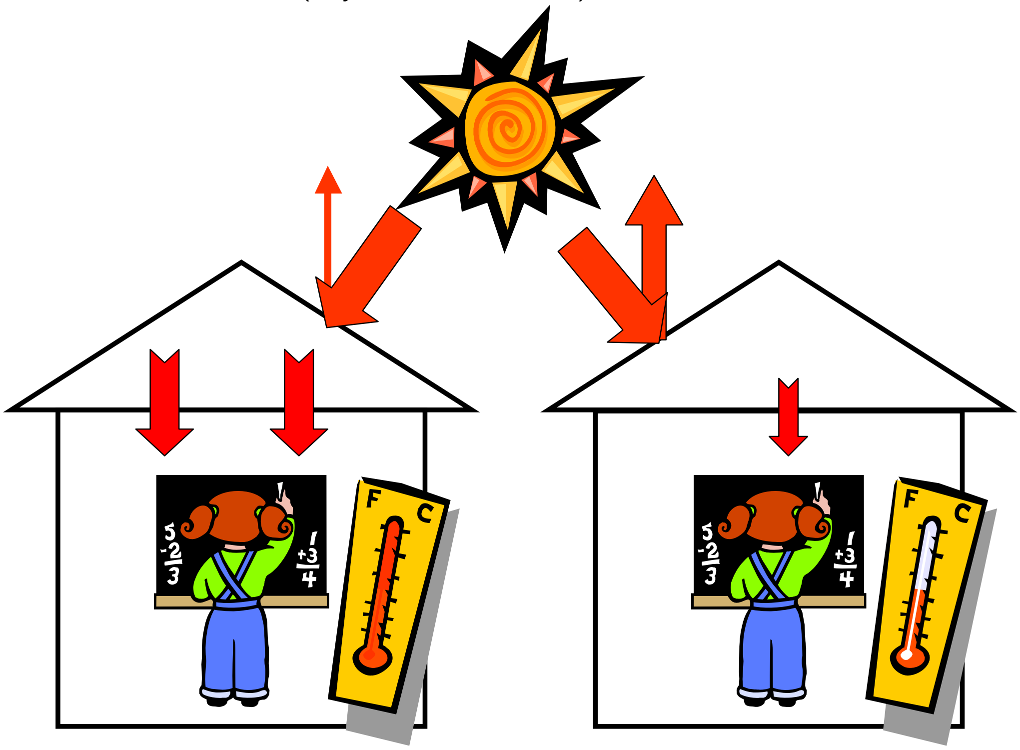
_________ colours absorb ________heat from the sun than light colours and this heat is then

_____________ ed to the box below making it __________. ________colours reflect more

heat and so don't heat up the box as much. When you add the aluminium foil this helps

to __________ even more of the heat away from the box, so temperatures are even _____.

Shade the roof that is darker (they are both uninsulated).



____ roofs _____ more heat and transfer it to the room

____ roofs _____ more heat and so rooms stay cooler

Thinking about building design

Buildings are not unlike boxes. Have a look at the colour of the roof of your classrooms, your home and your friends' places. Think about what you might do to test how roof colour is affecting the temperature of these buildings. Don't forget that some of them may have insulation and others not. What other characteristics of the buildings might also be influencing their temperature?

As you know, Queensland gets lots of sunshine and can get very hot in summer. Our schools and homes can be designed for this by:

- shading windows and walls with trees, wide roofs or verandas
- allowing sunshine inside only in winter
- using insulation in the roof and ceiling
- fitting doors and windows that can be opened to get cooling breezes.

Cooperative Research Centre for *Construction Innovation* (**www.construction-innovation.info**)

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AUTHOR BIOGRAPHIES

Michael Ambrose

Michael Ambrose is an environmental scientist with CSIRO Manufacturing and Infrastructure Technologies where he has been employed for the last 11 years. Michael holds a degree in architecture from Deakin University and has a graduate diploma in building project management. He is currently leading the CRC CI Sustainable Subdivisions project that is studying the link between land sub-division and the potential for energy efficient housing, including the incorporation of solar powered electricity production. He is also managing a CSIRO project, which is developing sophisticated long-term life cycle analysis software for water authorities allowing authorities to model management scenarios on their pipe infrastructure and predict both the economic and social consequences.

Michael's other recent projects include the analysis of energy embodied in buildings, material and cost estimating and the utilisation of CAD systems for environmental analysis. These have included projects for the Australian Greenhouse Office looking at energy efficiency of commonwealth housing and several embodied energy analysis projects for commercial, residential and infrastructure projects including an analysis of several urban water infrastructure options for a large residential sub-division. He also developed and managed environmental specifications for a Greensmart residential village recently opened in Brisbane, Australia.

Michael's background in architecture has been utilised in the LCADesign project and he has been responsible for developing the prototype CAD models and the interface between the 3D CAD software and LCADesign.

Anne Miller

Anne Miller is researcher with a CSIRO Manufacturing and Infrastructure Technology and was the researcher for this CRC-CI project. Anne undertook the research, analysis and reporting of the case studies and prepared this report. She is also the researcher for another CRC-CI Project, DISCOVER, which aims to build a demonstration and research dwelling at Brookwater.

Before joining CSIRO in April 2004, Anne was a researcher with the Australian Housing and Urban Research Institute Queensland Centre. She undertook research in various projects on policy issues associated with urban development, design and associated social issues and from a national and international perspective. During this period, Anne also lectured and tutored at the Queensland University of Technology.

Anne has a Bachelor of Built Environment and a Graduate Diploma [Interior Architecture] from the QUT. After graduating, she chose research in preference to practice. Prior to this mid career change, Anne's had more than fifteen years experience with the Australian Government focusing in a range of property related areas including project management, commercial property management and construction administration.