University of Southern Queensland

Faculty of Engineering and Surveying

Conceptual Design of a Sustainable Energy-Waste Solution for the Residential Sector

A dissertation submitted by

Nicholas Gould

in fulfilment of the requirements of

Courses ENG4111 and ENG4112 Research Project

Towards the degree of

Bachelor of Engineering (Environmental)

Submitted: October, 2009

Abstract

The project endeavours to derive a conceptual design of a Sustainable Energy-Waste Solution for the residential sector, based on innovations and lessons learned from the green building sector, specifically the 'Smart & Sustainable Homes Program' (SSHP) in QLD, as well as those employed in the city of Melbourne's 'council House 2' (CH2).

Various techniques will then be used to compare the design with CH2, which has been recognised as a world leader in sustainability through receiving a 6 Star rating under the Green star rating system.

In order to assess the requirements of the system, the conceptual design of an hypothetical house was undertaken and analysed in order to determine both the load required and the potential sustainability of the system.

As these are conceptual designs, they focus mainly on the aspects of each design task which have the greatest impact on the system as a whole. Thus, things such as in depth wiring, plumbing and fit out information is not included, unless it specifically informs some important aspect of the system.

University of Southern Queensland
Faculty of Engineering and Surveying

ENG4111 Research Project Part 1 & ENG4112 Research Project Part 2

Limitations of Use

Professor Frank Bullen
Dean
Faculty of Engineering and Surveying

Certification

I certify that the ideas, designs and experimental work, analysis and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Nicholas Gould

Student Number: 0050059025

Acknowledgements

I would like to thank Steven Goh, the originator of the project topic and my project supervisor. His advice and direction has been priceless - as has his humour.

I would also like to the the teams of the GreenStar and BASIX rating systems for allowing me to use their software for my analyses. In particular I would like to thank Kevin Yee from the NSW Department of Planning. His efforts to help me understand the BASIX system, and his assistance in arranging additional analysis by the BASIX team was truly exceptional.

I would especially like to thank my beautiful wife Elysha, without who's support I would probably have forgotten to eat, sleep and breathe while I was conducting the project.

I would also like to thank the open source movement for providing professional level software free to the public. Much of this software is written for it's usefulness rather than it's profitability and without it this work would have suffered.

Table of Contents

List of Figures

List of Tables

1.0 Introduction

The full title of this project, as offered by the USQ Faculty of Engineering and Surveying is “Conceptual design of a Sustainable Energy-Waste Solution for a Residential House as a basis for a Comparative Study with established 6 Star Building Designs in high-rise Buildings”.

Further to this additional guidance was given that the project “endeavours to derive a conceptual design for the residential sector based on innovations and lessons learned from the house design and construction of the Smart & Sustainable Homes program in QLD and to compare that to CH2.”

This understanding of the project informed the development of the project aims and the task objectives which are derived from them.

1.1 Project Aims

- The project endeavours to derive a conceptual design for the residential sector based on innovations and lessons learned from the house design and construction of the Smart & Sustainable Homes program in QLD;
- To compare that design solution to City of Melbourne’s Council House 2 (CH2);
- To promote greater understanding of green building and sustainability;
- To make selection of Sustainable Energy and Waste systems easier for those involved in the residential design/construction sector, where appropriate.

1.2 Derived Objectives

The following objectives have been derived from the Project Aims, in order to provide greater detail and clarity on the task.

1.2.1 General Research

- To provide a literature review of innovations in the Sustainable Housing and Green Building sector; and specifically,
- To research the sustainable building principles employed in the CH2 building, a world leader in sustainability;
- To research the sustainable building principles employed in Queensland's Smart and Sustainable Homes Program (SSHP);

- Research the Green Star rating system as well as other rating systems; and
- To develop an appropriate research methodology to investigate the specific goals.

1.2.2 Specific Goals

- Investigate and evaluate Energy and Waste solutions employed in SSHP and CH2
- Investigate and evaluate alternate energy-waste solutions from literature;
- Determine influencing factors in the selection of Energy and Waste technologies;
- Evaluate and select a rating System, or other means of comparison;
- Compare the conceptual design solution to the design in CH2 & SSHP;
- Create a decision-making matrix for the Residential Construction Sector (time permitting).

In order to determine the design constraints for the system it is necessary to know the loads that are expected to be generated by the residence. However, as discovered in the literature review, by designing the entire building using green building principles one can minimise the demand placed on any energy-waste system, thereby potentially improving the sustainability of the system and of the house as a whole.

Almost all of the literature on sustainability, environmental design and other related fields points to the fact that design and problem solving CANNOT be undertaken in vacuo. In designing an energy and waste solution for a house, one must understand the house as a dynamic system. It is most important to recognise that many factors have significant impacts on both energy and waste patterns, and therefore, the house's sustainability. It is ultimately determined by the design of the house, but also it's location, the number of occupants, their lifestyles, local weather patterns, global weather patterns, materials and even colour. As part of a larger picture, the values and attitudes of society, market conditions and global environmental processes all affect these smaller systems as well.

As such this project will initially investigate the conceptual design of a sustainable, free-standing, single family dwelling (house), and seek to determine the Energy improvements that such designs offer. This project will thus attempt to assimilate the best facets of sustainable design as exhibited in the Qld “Smart and Sustainable Homes” program and CH2, and utilize these features to design the best possible, sustainable house.

Having determined the load required for a sustainable system, design was then undertaken to best match the available technologies to the system requirements. The value of the overall Energy-Waste System, including demand minimisation measures, will be rated and compared to CH2 using various techniques applicable to this particular case.

Unfortunately, due to the limited information available on CH2, the conceptual nature of the design, as well as the inherent difficulties of comparing a residential house with a multi story office building, there was no standard basis for comparison. As such, in addition to the design work of the project a means of comparison was developed using the information which was available.

1.3 Background

CH2 , Council house 2, is a multi story office building located in Melbourne. It has used many green building and sustainability principles in its design and construction and provides an aspirational role model for green buildings, both in terms of performance, and the holistic design approach which has provided benefits across a variety of aspects of the building experience.

The Smart and Sustainable Homes Program (SSHP) in Queensland, provides a wealth of information on sustainable green building practices as well as built examples of climate relevant strategies in different locations. This resource informs much of the decisions regarding the pursuit of project aims and objectives.

2.0 Literature Review.

This literature review was undertaken in order to facilitate a greater understanding of the issues involved with the stated project aims. As such it will seek to provide an overview of the context of this project as well as pursuing the task oriented research goals outlined in the project's Derived Objectives.

The review examines the importance of sustainability and the relevance of green building. It examines important principles in green building, particularly with regards to sustainable energy and waste solutions. It will also examine residential energy consumption, minimisation strategies for both energy and waste, and the types of technologies which can be employed in their delivery.

2.1 Background Concepts

2.1.1 Sustainability

The importance of sustainable practices is outlined by the 'ENGINEERS AUSTRALIA POLICY ON SUSTAINABILITY ' (Institution of Engineers, 1999).

> **"Sustainability is the ability to maintain a high quality of life for all people, both now and in the future, while ensuring the maintenance of the ecological processes on which life depends and the continued availability of the natural resources needed."**

The policy also emphasizes the need for Engineers to understand the 'significant adverse Consequences' of failing to achieve environmental sustainability. (Institution of Engineers, 1999) It is also understood at a professional level that large amounts of environmental degradation that threaten the sustainability of our future are caused by human activity (Nervegna L, 2006) and that our potential to address these environmental issues, like our ability to cause them, is linked strongly to our increasing level of technology and the means in which it is employed (Roger, 2000).

All human activity henceforth must seek to address these imbalances in order to maintain a viable future.(Nervegna L, 2006)This involves, but is not limited to reducing and eliminating unsustainable patterns of production and consumption.(Institution of Engineers, 1999) In addition sustainability demands that we re-examine engineering projects, and all of their functional and material components, in order to identify and maximise opportunities for sustainability.(Institution of Engineers, 1999)

2.1.2 Climate Change and Greenhouse Gases

Anomalous changes in climate patterns can have detrimental environmental impact. Australia is identified as being particularly vulnerable. Key concerns include threats to the biodiversity of rich natural systems, water supply problems and sea level rises (Dept of Env, 2008) which threaten Australia's high proportion of coastal settlements.

It is the Australian governments official position that CFCs and Green House Gases contribute to climate change. This is reflected by information contained on it's climate change website: <www.climatechange.gov.au>

It is apparent that buildings, and their use account for a large proportion of GHG emissions (Miller P, 2009). This is reflected graphically in Figures 2 & 3 on the next page. Figure 2 shows the amount of money which can be saved by reducing GHG emissions, while figure 3 shows reductions which have no appreciable financial return. Areas which are sectioned in blue are related to building emissions These figures are taken from Miller P, 2009 in 'National Geographic'.

It is interesting to note that approximately 40% of notable GHG reductions save money. (Miller P, 2009) though the total amount saved seems to exceed the cost of the cuts with no financial benefit. Therefore, GHG reductions approximate zero economic cost . This is in addition to the clear advantage of reducing environmental destruction and facilitating sustainability.

It is easy to see from this information that many aspects of our domestic life have a dramatic effect on the environment and the sustainability of our nation, and our planet. The following diagram shows the major sources of emissions created by private individuals. While travel contributes significantly to individual emissions, a majority of sources come from within the home.

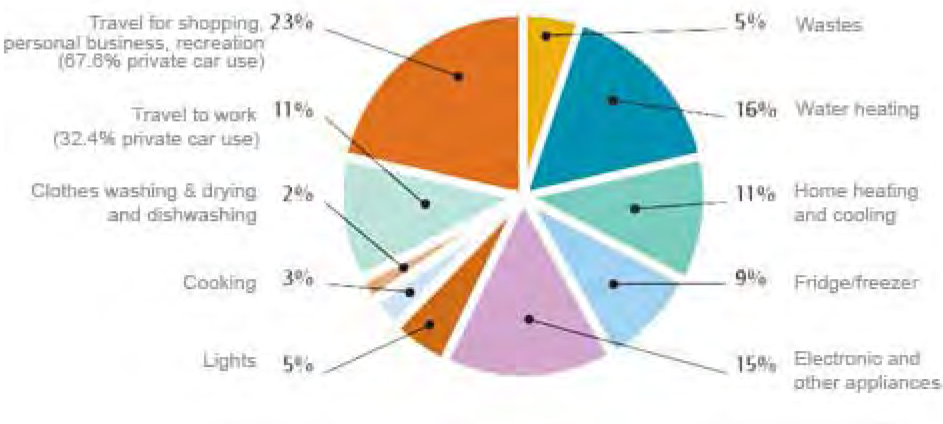


Figure 1: Greenhouse emissions for Individuals (Dept of Env, 2008)

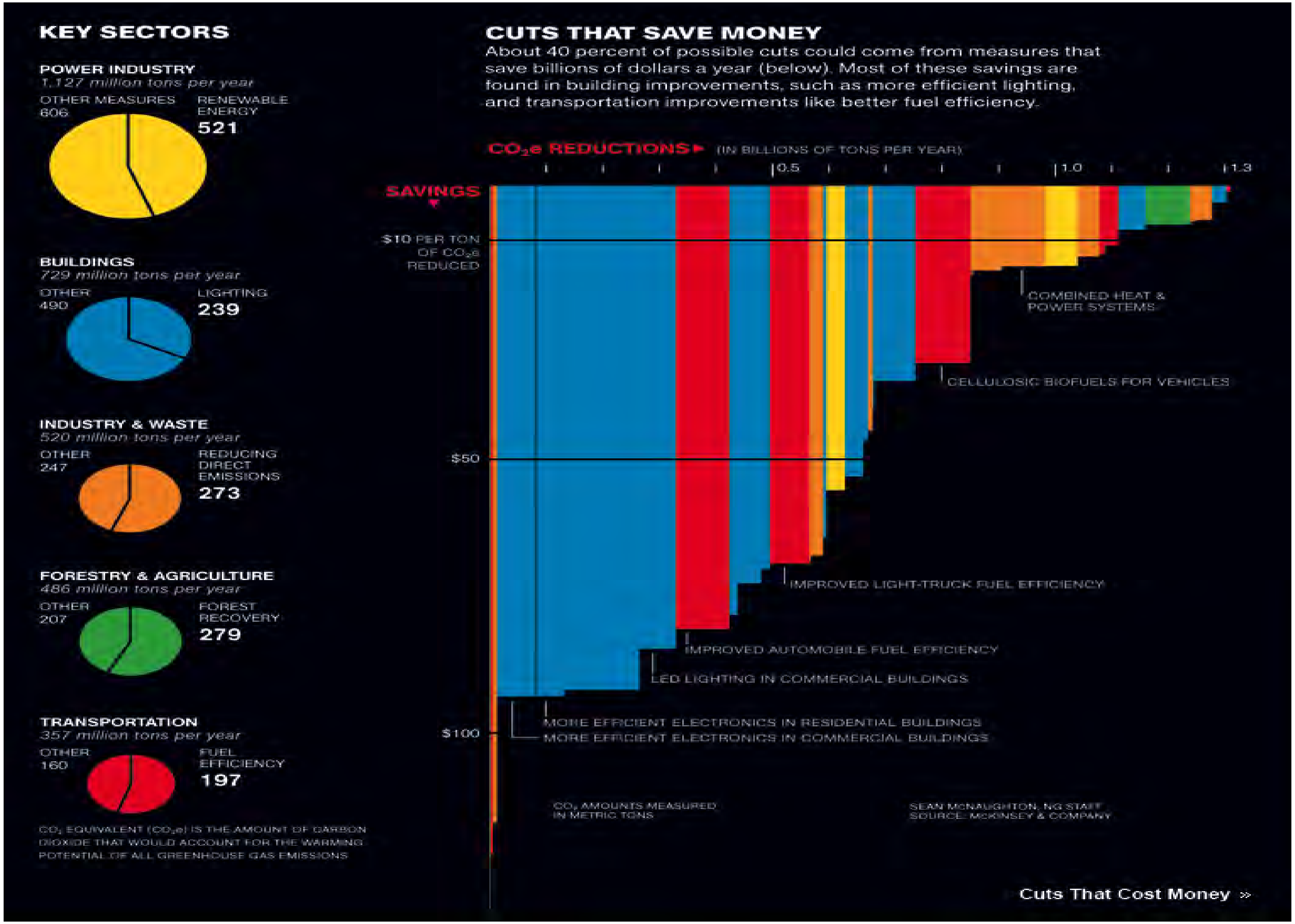


Figure 2: Savings for Greenhouse Gas Reductions (Miller P, 2009-National Geographic)

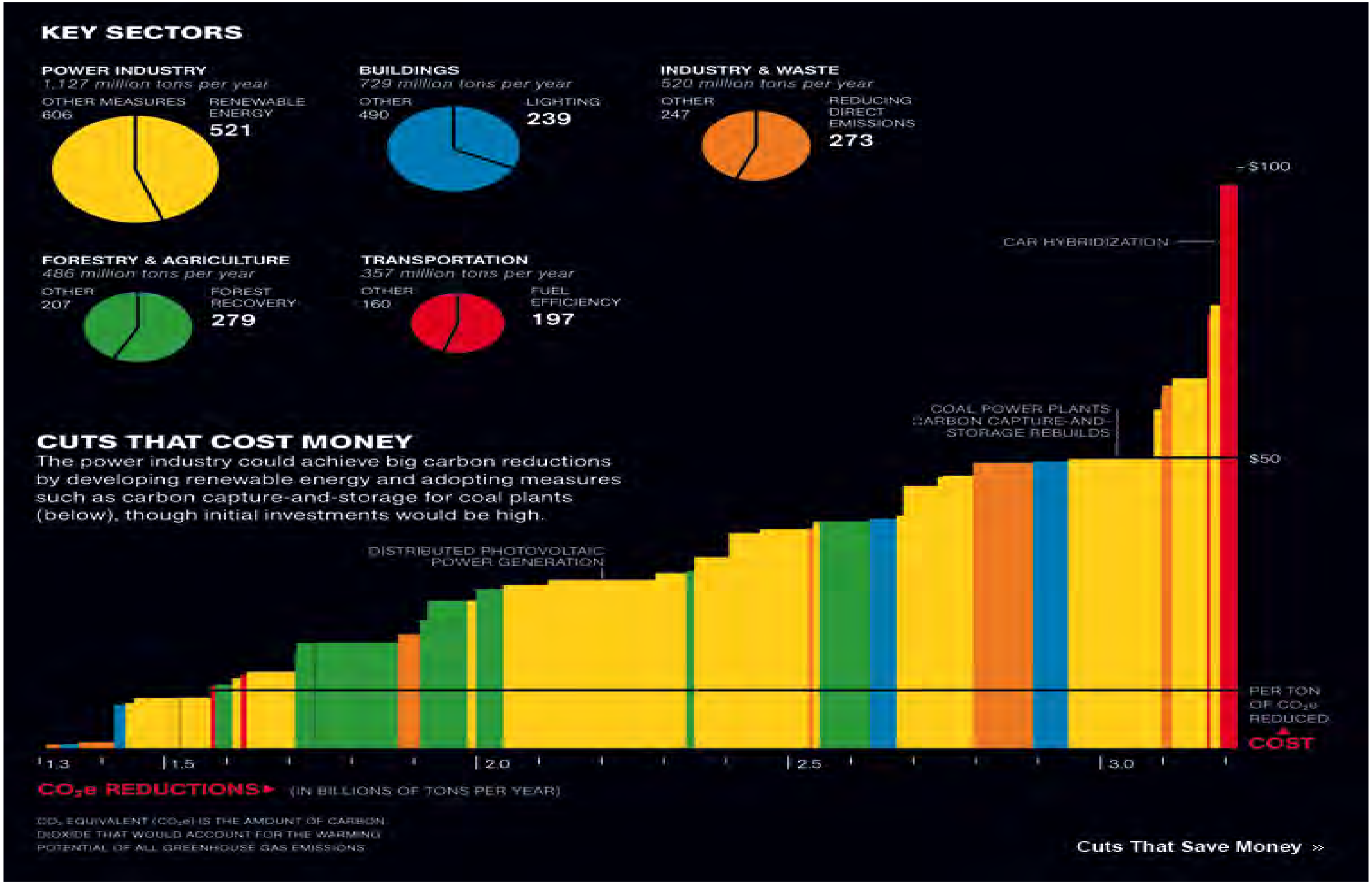


Figure 3: Costs for Greenhouse Gas Reductions (Miller P, 2009-National Geographic)

2.1.3 Sustainable Homes

Sustainable housing addresses the triple bottom line criteria of social (human), economic and environmental impacts of housing (Department of Infrastructure and Planning, 2007-2009a).

In order to address important aspects of the “human” dimension the “Your Home” Technical Manual <www.yourhome.gov.au/technical>, created by the Australian government, recommends many specific strategies including allowing for changing demands as occupants age, in addition to addressing general safety and security. (Department of Climate Change, 2008)

The Smart and Sustainable Homes Program provides a greater scope and depth in it's list of 10 tips for sustainability, addressing the major social and environmental factors in sustainable design. It's ten tips are as follows.

1. **Water conservation,** using efficient fittings, rainwater and greywater harvesting.
2. **Natural heating and cooling (**passive solar design**)**
3. **Energy and greenhouse efficient water heating:** solar, natural gas or electric heat pump
4. **Future-proof:** easy access to essential rooms upon entry.
5. **Safe floors**
6. **Address the street - lighting** and separated driveway and pedestrian entries
7. **Casual surveillance**
8. **Use low maintenance materials**.
9. **Indoor air quality** Avoid volatile organic compounds (VOC’s),
10. **Outdoor living** Include permanently covered outdoor areas

(Smart and Sustainable Homes Program, 2008a)

The Environmental Sustainability of houses relates to the impact of housing and the built environment on areas such as natural resource depletion, greenhouse gas emissions, salinity and water management and unsustainable industrial processes. More importantly it relates to the way in which these impacts can be addressed and minimised to sustainable levels (Nervegna L, 2006).

The design process used in this report will seek to focus specifically on Environmental Sustainable design (green building), whilst acknowledging the importance of holistic design, which addresses all aspects of sustainability and building design.

2.1.4 Green Building

> **"Buildings and the built environment play a major role in the human impact on the natural environment and on the quality of life; sustainable design integrates consideration of resource and energy efficiency, healthy buildings and materials, ecologically and socially sensitive land-use, and an aesthetic sensitivity that inspires, affirms and ennobles; sustainable design can significantly reduce adverse human impacts on the natural environment while simultaneously improving quality of life and economic well being."**

(RAIA, 2001)

The process of green building involves an analysis of all of the components of the design and the way in which they affect each other and the building as a whole. This approach incorporates the understanding that higher costs for individual aspects of a design may still result in reduced overall costs, due to the inter related nature of building issues. It specifically addresses such issues as building design, energy and water efficiency, resource-efficient construction, lighting and mechanical design, and building ecology (The Rocky Mountain Institute, 2009).

It is also important that all phases of a building's life cycle be considered. This means that sustainability principles must me employed in regards to the construction, operation and demolition of buildings and that suitable consideration is given to these elements during design (Nervegna L, 2006). This is particularly important because of the impacts of our building construction processes that use vast amounts of material and energy (Roger, 2000).

In 1999, the building sector, in conjunction with the Ministerial Council on Greenhouse, developed a systematic endorsement of energy efficiency in order to address some of these environmental concerns. This system encouraged increased thermal comfort through building design whilst reducing residential emissions. It proscribed a minimum efficiency level and also developed the House Energy rating scheme (HERS), in order to assess it. (ABS, 2006) After several incarnations, HERS (as NatHERS) now underlies most of the building assessment software available in Australia

2.2 Green Building Design

2.2.1 The Importance of Design

Building design is of paramount importance in the design of a sustainable energy-waste solution. By applying green building principles operational energy needs are minimised, allowing a range of renewable energy sources to proved the supplementary energy needs, either in the form of heat, movement or electricity (Prasad & Fox , 2001).

Some of the major principals emphasized in the current design/construction of green buildings are natural ventilation, shading in summer, access to winter sun for heating, in addition to mainstream construction practices which regulate the quality and safety of buildings. These aspects of green design are particularly emphasized because, they provide the opportunity to reduce heating and cooling requirements and thus energy supply and greenhouse emissions (Environmental Protection Agency, 2008a)

2.2.2 Holism and Systems Design

As applied to building design, holism seeks to address all aspects of the building and integrate them into a cohesive whole. (Prasad & Fox , 2001) In application this is rarely the case with holistic design tending to focus on more traditional aspects such as those outlined in Figure 4.

The holistic design process involves the simultaneous interaction and input of as many stakeholders as possible. This facilitates greater understanding of the interrelation and interconnectivity of separate aspects of a building's design (Wall, 2000). When a greater number of different viewpoints and fields of specialisation are included in the design process it is likely to become more truly holistic.

Systems design approaches the building itself, as well as all of its component elements, as systems with their own inputs, outputs and internal processes. As a result, an understanding of the environmental impact of various inputs and outputs of house related systems can identify the need to reduce the scale of their impact. This is achieved by attempting to recycle all outputs as inputs for other processes, thus reducing or eliminating the house system throughput (Rodger, 2000).

The following figure may be useful in order to illustrate the inter related nature of systems. While it is by no means exhaustive, Figure 5 illustrates some aspects of the building thermal energy system and related systems such as climate and lighting.(Wall, 2000)

An holistic approach to building design examines:

- Urban density and planning
- Site planning and landscaping
- Materials selection, embodied energy, off-gassing
- Energy demand minimisation
- Indoor air quality and comfort
- Energy supply options
- Renewable energy integration
- Waste/water management and recycling
- User behaviour.

Figure 4: Holism (Prasad & Fox , 2001)

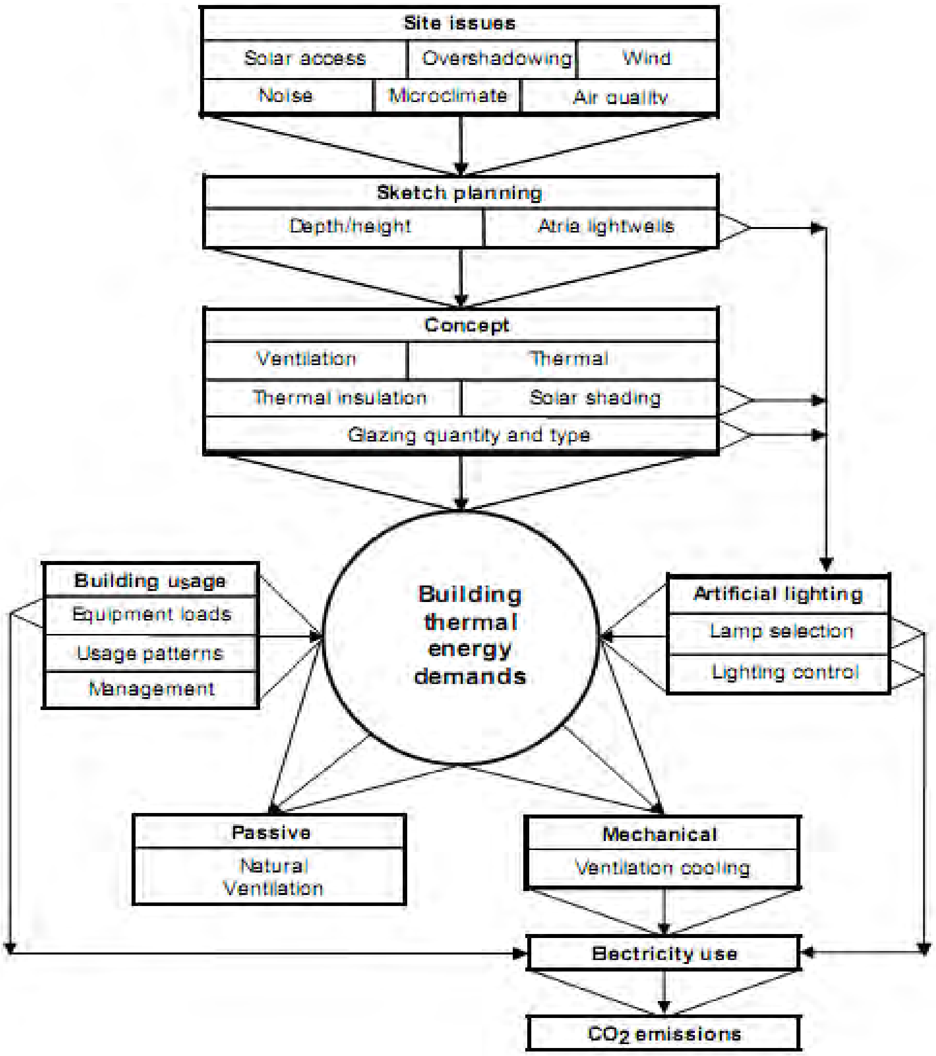


Figure 5: Systems (Wall, 2000)

2.2.3 Architecture, Mind and Lifestyle

'Our mental landscapes give shape to the built environment,

and the built environment gives shape to our mental landscapes.

Unsustainable design is a result of unsustainable mental landscapes.'

(Engwicht D, 2003)

Implicit in this statement is the understanding that the architecture and interior design of a building can be used to promote and reinforce a mindset and lifestyle of sustainability. Such a mindset leads to sustainable actions, which furthers the environmental benefit of the household.

This is of particular importance since the mindset and resultant lifestyle of a building's occupants cannot be compensated for in terms of materialistically focused design features. (Department of Climate Change, 2008) The effect of limited mindsets is evidenced in the unsustainable building practices which permeate our design and construction paradigm. (Department of Climate Change, 2008) One of the major influencing factors could be the prevalence of economically cheap and easily availably fossil fuels which foster a mentality promoting increased energy use as the answer to design constraints.(Department of Climate Change, 2008)

2.3 Green Design Techniques

The green building movement has identified several aspects of design which should be addressed in any building's consideration, as well as providing some prescribed measures which are usually applicable to great effect. The major considerations in green design are as follows.

- maximise insulation
- Orient the building wisely, and make use of appropriate shading and insulated mass.
- Strongly consider solar hot water service.
- Strongly consider rainwater collection for at least some of water demand.
- Choose the most energy-efficient appliances.
- reducing house size can significantly reduce the demands on various systems.
- Waterless sanitation makes autonomous water systems easier and cheaper
- Address issues such as stormwater management, and behavioural issues such as waste and transport decisions.

(Vale, 2003)

- Shading, position and size of windows
- Thermal mass
- Ventilation and infiltration
- User patterns and thermal comfort.

  (Prasad & Fox , 2001)

- Grouping rooms by use

  (Environmental Protection Agency, 2008a)

These design considerations are all important for different reasons and some even have reasonably universal solutions. For example the orientation of the walls and windows effects the amount of heat entering a home. However, most areas of Australia simply require that the building and major windows have a north facing (Environmental Protection Agency, 2008a). In addition an open plan and northerly orientation improves the potential for natural ventilation.(Environmental Protection Agency, 2008b)The EPA recommends that living areas are positioned 'to capture winter sun and summer breezes' (Environmental Protection Agency, 2008b) As such the Ideal location is on the northern façade.

Window characteristics such as size, and location should be optimised to avoid summer sun and optimise winter sun. (Environmental Protection Agency, 2008b) North facing widows most easily fulfil this requirement with western window being the worst. (Environmental Protection Agency, 2008a) This explains the EPA's directive to minimise windows on the western side to avoid the afternoon sun. (Environmental Protection Agency, 2008b) It is also important to install awnings and eaves to unwanted solar penetration and thus reduce heat. (Environmental Protection Agency, 2008b) To achieve this, it is recommended that homes in south east Queensland have eaves have a width no less than half of the tallest window which they shade (Environmental Protection Agency, 2008a).

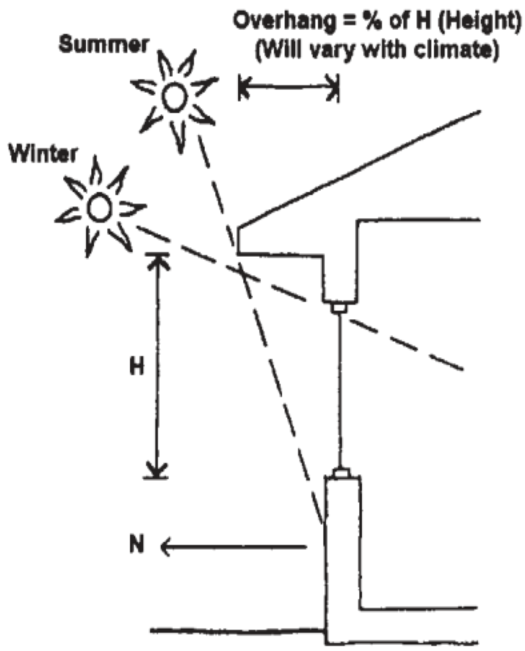


Figure 6: "Energy Efficient Home Design" - EPA

Window location can also have an effect on the ventilation of spaces and therefore their thermal comfort. (Environmental Protection Agency, 2008a)

'Zoning' rooms involves locating them in conjunction with compatible rooms , in much the same way as land use compatibility is zoned. By co-locating all rooms which use hot water, piping between rooms is reduced as is the heat lost through such piping. (Environmental Protection Agency, 2008a) As such it is recommended that, as a minimum, the Bathroom, kitchen and laundry should be located close to the hot water system.(Environmental Protection Agency, 2008b)

In addition, the following design features are recommended by the EPA.

- Use materials with low long-term maintenance costs.
- Install insulation in roof, ceiling and walls.
- Install compact fluorescent lighting including down-lights with efficient 12 volt task lighting.
- Paint the exterior of your house and roof in a light colour to help cooling.
- Consider an insulated skylight to let in natural light and not heat.

(Environmental Protection Agency, 2008b)

2.3.1 Thermal loads

Thermal loads in buildings present a problem because the temperature of a building may not be deemed to be comfortable by its occupants. Techniques exist to determine the actual temperature experienced by occupants, which is a function of radiative and convective parameters and therefore strongly tied to ventilation (Luther & de Dear , 2003).

The degree of comfort is a highly subjective matter, however it is worth noting that human physiology allows for significant variation of temperatures without adverse effect (Department of Climate Change, 2008). A building's occupants are also less likely to need additional heating and cooling if they dress appropriately for the conditions.

Since a large amount of energy used in the home is dedicated to achieving these desired temperatures, measures, both passive and active which address this thermal Loading can have a significant effect on energy use (ABS, 2006). As such the BCAs Energy star rating system provides different target scores for each Climatic zone (Building council of Australia, n.d).

Accurate assessment of thermal load is important as it can determine the efficiency with which heating and cooling systems operate. In addition sustainable homes require much less heating and cooling due to their adoption of passive features.(Department of Climate Change, 2008)

2.3.2 HVAC

The heating ventilation and cooling (HVAC) of a building is essential in addressing thermal loads which exceed comfort levels. In addition, adequate ventilation reduces threats from various pathogens - biological, chemical and particulate (Dept Health & Ageing, 2002). There are several passive design features which optimise ventilation and minimise the need for additional heating and cooling (Environmental Protection Agency, 2008a).

Radiative heat exchange is the most effective means of addressing heating and cooling requirements. This involves thermal masses which are usually heated or cooled by water, radiating or absorbing radiated heat. (Cheung, 2006) Underfloor radiant heating is close to ideal (ed. Hall, 2006). It warms the lower extremities while keeping the face and head comfortable, a factor which has been shown to affect mental performance(ed. Hall, 2006). It can also use low grade heat, which is often produced as a wasted by product of other systems or exhausted through ventilation.

Combining such underfloor systems with ground source heat pumps is good practice as the water pumped through an underground piping network becomes the same temperature as the ground, which maintains the yearly average temperature at an easily accessible depth (ed. Hall, 2006). Thus these systems provide radiative heating and cooling at optimal temperatures.

Displacement ventilation systems only deliver the amount of ventilation required to deliver fresh air supply and is typically smaller system than those that use ventilation to deliver heating and cooling (Cheung, 2006). This has important implications for the design of the Energy system which supplies it.The air gains heat from the occupants and equipment thermal buoyancy effects cause the air to rise up towards the ceiling, where it is then removed through ceiling-mounted exhausts. Thermal buoyancy driven displacement-type ventilation systems deliver cool air at low levels in a room, which then rises to be collected from the ceiling. This also means that a greater proportion of air in a space is fresh, as stale air soon rises to make room for the fresh.(Cheung, 2006)

2.3.3 Insulation

Insulation is important because it can greatly reduce energy consumption.(ABS, 2006) In fact , installing insulation can be the most effective way to address thermal loading that would other wise be dealt with by other systems (Environmental Protection Agency, 2008a). Since the load on systems, such as HVAC, is reduced, the size of these components can be reduced. They can also be operated more efficiently and at a lower cost than systems which must cope with the wide variation of temperatures caused by poor insulation (ed. Hall, 2006).

It is important to note that insulation is less effective in poorly ventilated houses and houses with large, unshaded windows (Environmental Protection Agency, 2008a) and that insulating pipes is important and may make the most important contribution to reducing heating and cooling bills. (Department of Climate Change, 2008)

2.3.4 Materials

The materials used in constructing a building are extremely important in that they can have a great effect on other systems in the building. In particular, The materials used for the walls of building have a significant effect on the thermal properties of the building (ABS, 2006). Thus the thermal comfort of occupants, HVAC and ultimately, energy systems, are all effected.

The materials themselves are products of a fabrication system requiring various inputs, noticeable energy and base materials. Greenhouse gases are also emitted as a consequence of the operational and embodied energy associated with all buildings. The energy embodied in materials can represent a large contribution to the overall energy use of a building.(Treloar & Fay, 2005)

The Built Design and Environment Guide identifies desirable material features as:

- reused and recycled materials;
- materials with zero or low harmful emissions and toxicity;
- materials with high recycle potential, durability and longevity;
- materials that require less maintenance and have lower replacement costs over the life of the building; and
- materials that have greater flexibility under changing design requirements over the life of the building.

(Treloar & Fay, 2005)

These points are indicative of an understanding which assess the impact of the material over it's entire life cycle. This is important because in assessing the impact of a material one must consider the base component and it's associated features, manufacture, transport, installation, maintenance, and finally demolition and recycling (CH2, 2006a).

In addition to the insulative properties of building materials, the Thermal Mass of a material can play an important role on the Thermal Load. The thermal mass of a material refers to it's ability to store heat (ed. Hall, 2006). Construction materials such as concrete and brick absorb and hold heat, which is then released when the air becomes cooler (Environmental Protection Agency, 2008a). This is ideal for locations where excess heat in the day is needed for heating at night.

Insulation of these high thermal mass materials is often a good idea as thermal mass typically does not replace the need, or the building code requirements, for insulation. This is particularly true in hot, humid areas where thermal mass can often lead to around the clock heat instead of cooling.(Environmental Protection Agency, 2008a)In such cases it is often advised to use lightweight high insulation, low thermal weight, building materials.(Environmental Protection Agency, 2008a)

Thus it is necessary to have a range of materials which can be used for both either insulation or thermal massing, depending on the location specific needs. Two materials seemed to have the optimal properties required of a green building material. These were Straw bale construction and Rammed earth/cob building.

- Rammed earth, has low embodied energy, low GHG emissions, high fire and Vermin resistance and High Thermal Mass. Ideal for locations where diurnal temperature variation could be used to cool in the day, and 'heat' at night.

- Straw Bale Construction: has high values for insulation, low thermal mass, low embodied energy, low to negative GHG emissions, high fire and vermin resistance. Ideal for locations requiring low thermal mass, and high insulation. Particularly suited to tropical and subtropical areas which benefit from light weight, highly insulative materials (Department of Climate Change, 2008).

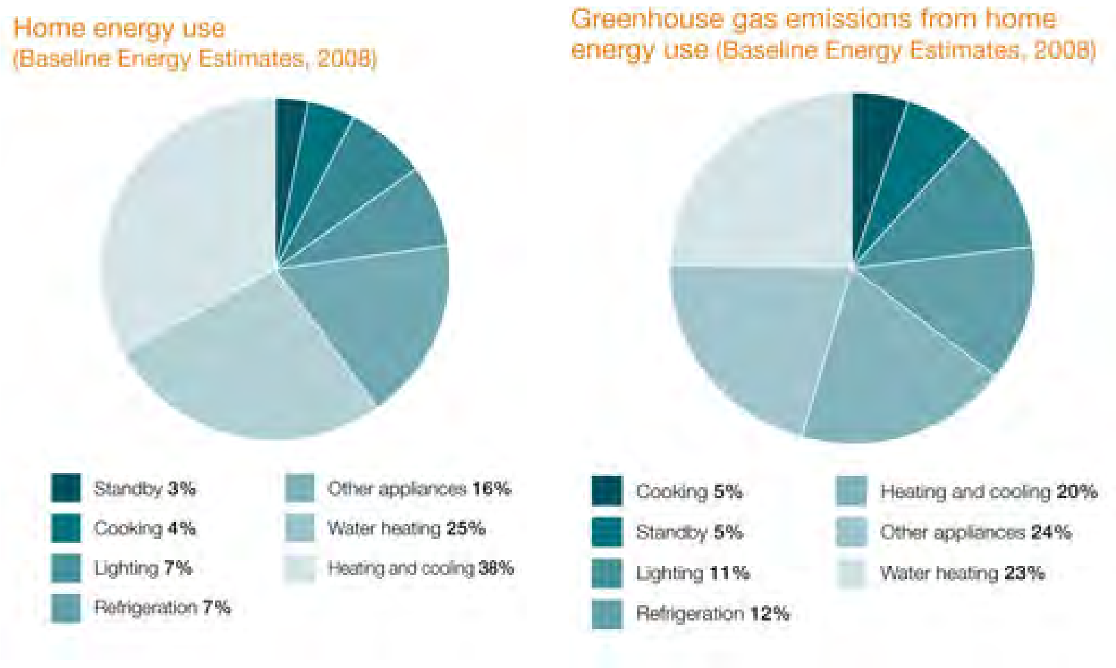
2.3.4 Passive Lighting & Colour

> **Light and colour have an appreciable affect on human physiology and the human psyche, with light related sensory information being fed into areas of the brain associated with emotion and hormone production. Physical responses to colour may be measured using bio-indicators[...] As such, great thought should be given to the allocation of colour within a building. When assessing the lighting mix for any of these visual interaction it is important to recognise that Natural light provides great physical and mental health benefits.**

(Altomonte, 2006)

As has been mentioned in previous sections, good passive design locates windows wisely, and with appropriate shading, so that heat gain and loss can be optimised as required for the house. As a result, daylighting of rooms is most likely on the northern façade of the house, where windows are used to absorb heat from the winter sun. The use of natural lighting reduces demand on electric lighting systems, thus having an effect on the demand placed on any energy supply system for the building. Daylight also plays an important role in the physiological processes of it's occupants and therefore has benefits beyond economic and energy costs. However, in practice an emphasis on passive lighting should not result in unwanted excessive heat gain or loss. Generally, the energy saved through daylighting should be greater than the energy lost through changes in thermal load. (Department of Climate Change, 2008)

2.4 Energy



Figures 7 & 8: Domestic Energy use, by type, and Emissions (Department of Climate Change, 2008)

The above figures show the relative proportions of energy uses within the home. From these figures it is easy to see why design measures to address the thermal loading of buildings are so important, and why such emphasis is placed on them in the literature. The enforced obsolescence of electrical hot water systems is also hugely important, with the more efficient technologies that replace them aimed at reducing the sizeable contribution of the water heating component.

In addition to the energy used by appliances, these factors represent more than two thirds of domestic GHG emissions and more that three quarters of energy use.

2.4.1 Construction

Our urban systems and the buildings that form such important parts of them are brought into being only through construction processes that use vast amounts of material and energy.

(Roger, 2000)

In addition to the energy used for construction, significant amounts of energy are used in the creation, modification and transportation of the materials used (see Materials). As such a building can be seen as the sum of energies required to construct it, both in form and material.

2.4.2 Operations

Built environments are able to provide the life support services for which they were designed and built only when they are continuously supplied with a flow of material and energy resources. These include water, food, gas, electricity, liquid fuels, paper, raw and processed materials and manufactured products. Behind each of these there are further environmental impacts attributable to their production.

Of particular importance are the environmental impacts and energy implications of the urban food systems through all its various stages: agriculture and horticulture, transport, processing, packaging, refrigeration, storage, wholesaling, retailing, display, collection by the purchaser, further processing and then disposal of all the wastes from the food and its packaging. Collectively these represent a major component of total environmental impact and energy use. (Institution of Engineers, 1999)

It is interesting to note here that there is significant opportunity to reduce energy inputs and waste outputs if food gardening is integrated into the house design system.

The following breakdown of energy use and GHG emissions is slightly different from that provided in the “Your Home- Technical Manual” (Department of Climate Change, 2008), however it is still very useful in emphasising the most energy intensive utilisation methods. Major attempts to remedy the heating and cooling requirements have already been discussed. Methods for addressing energy demand created by appliances, water heating, cooking and energy follow.

	Energy use %	Emissions %
Appliances(a)	30.0	53.0
Heating water	27.0	28.0
Cooking	4.0	6.0
Heating and cooling	39.0	14.0
Total	100.0	100.0

Table 1: Use of energy in the household by purpose and related greenhouse gas emissions (ABS, 2006)

Appliances & Water Heating

While appliances account for a significant amount of residential energy demand, there are many simple techniques which can minimise their energy use. The use of energy efficient appliances is the most important.

By providing incentives to purchase efficient appliances, a municipal council in Texas saved enough energy to stop a coal fired power station from being built. This resulted in a lower economic and environmental cost, comparable to the power station, simply by addressing appliance efficiency. (Miller P, 2009 'National Geographic')

In addition to appliance efficiency it is important to switch appliances off when they are not in use, or use timers to limit available supply (Dept of Env, 2008).

Cooking

Cooking in ovens is the least efficient means of cooking, although fan forced ovens offer a considerable improvement of around 35%. Alternatives to ovens should be used at all times, gas an microwave cooking generates 30-50% of the GHG generated by electrical cooking. Correct use of lids and pressure cookers can also reduce the emissions associated with boiling by half. (Dept of Env, 2008)

Design Loads

The expected load to be dealt with by an energy-waste system is a key factor in determining the systems and technologies used to meet those requirements. Depending on individual circumstances, building goals, and choice of ratings, different energy design loads may be considered in the design process.

The BCA however, specifies a minimum star rating, presently 5 stars for Queensland, which must be achieved by new buildings. This rating refers to the energy used by the building shell in order to maintain a comfortable interior. Thus it includes heating and cooling systems which are part of the building, but not energy used by occupant appliances. The specific values required to reach such values varies in each of the different climate zones. For Brisbane and similar areas the values for achieving each star or half star rating (fro 0.5 to 10 stars) are as follows (in MJ/M^2).

0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
245	203	167	139	116	97	83	71	62	55	48	43	38	34	30	25	21	17	13	10

Table 2: Energy use per star, Brisbane (Building council of Australia, n.d)

It is important to remember that these star ratings are only one aspect of building energy use, and that 5 stars is presently the *minimum* acceptable value. As such, the design load used for this project will seek to exceed the minimum by a great margin.

Energy Sources

The ABS provides the following breakdown of residential energy consumptions by type. (ABS, 2006)

RESIDENTIAL ENERGY CONSUMPTION

	1983–84	1993–94	2003–04	2029–30(a)
Energy source	%	%	%	%
Electricity	42.6	42.4	48.7	50.8
Natural gas	23.9	28.3	31.2	33.7
Wood(b)	25.1	23.7	15.9	10.4

Heating oil	2.5	1.1	0.0	0.0
Solar energy	0.7	0.7	0.6	0.7
LPG	2.1	2.6	2.7	3.2
Other(c)	3.0	1.1	1.0	1.2
Total	100.0	100.0	100.0	100.0
	PJ	PJ	PJ	PJ
Total	276.0	344.4	420.8	650.8
	GJ/person	GJ/person	GJ/person	GJ/person
Total	17.7	19.3	20.9	26.3

Table 3: Residential Energy Consumption (ABS 2006)

Reducing domestic energy demands is particularly important as energy production is responsible for over two thirds of Australian GHG emissions.(ABS, 2006)**With 92% of electricity produced using fossil fuels.** (ABS, 2006)

Natural gas is considered to be a more environmentally sound alternative to electricity, Producing one third of the GHG emissions of equivalent electricity.(ABS, 2006)Thus it is easy to see why gas is recommended as an alternative source of hot water or for boosting solar systems, as well as for replacing inefficient cooking technologies.

In addition to the problems associated with producing electricity there are huge energy losses occurring during transmission.(Miller P, 2009)This means that even "green energy" purchased from the grid has huge inefficiencies associated with it.

However it has now been proven that significant amounts of building heat and energy requirements can be met on site, through the use of renewable technologies, resulting in very low GHG emissions (Prasad & Fox , 2001). This is clearly ideal from a systems perspective as these technologies tend to have inexhaustible inputs, and minimal wasted outputs. For example Photovoltaic systems generate electricity on site with minimal transmission losses. (Prasad & Fox , 2001) The cost of photovoltaic systems in Australia varies widely with subsidies, typical values in the UK are 7000-9000 lbs per kw (ed. Hall, 2006) . It is currently possible to get 1kw grid systems for less than AUD $7000.

Solar energy is one of the cleanest sources of renewable electricity, with very low GHG emissions(ABS, 2006) and eliminates electricity bills for the lifetime of the system. (Environmental Protection Agency, 2008b) The ease of operation and low maintenance requirements also make them attractive options for green buildings. (Prasad & Fox , 2001)

Biogas produced on site is also an interesting option for the production of heat. It's on site production gives it advantages over other forms of gas in that the energy used in it's production and distribution is greatly reduced. (Low Impact Living Institute, n.d) Though typical household systems only supply enough gas for cooking though as noted earlier this typically accounts for 4% of domestic energy use. (Fortune Magazine, 2008)

Combined heat and power systems use a combustion engine and turbine to create electrical supply while using the waste heat to address thermal comfort. Technologies such as the 'whispergen' Stirling engine CHP, deliver 1kw electrical, and 7.5-13kw of heat (ed. Hall, 2006). This would be a valid option in cold climates where heating loads cannot be met by passive or solar thermal heating, such as the system described in the 1979 solar house case study (see Case Studies.)

Domestic Wind power is able to supply significant amounts of power at comparative costs. The main factor in the selection of wind power is that the mean wind speed at the site must be significant in order to achieve optimal output (ed. Hall, 2006). While this may not be suited to every location it is certainly suitable for some, especially where high winds and low solar radiation are common. The following table gives and indication of the windspeed required to achieve related outputs.

Rotor Diameter	1.13	1	1.25	1.5	1.75	2
	Output in watts					
Wind speed						
10	190	150	230	340	460	650
11	250	200	310	450	610	870
12	330	260	410	590	800	1130
13	420	330	520	750	1020	1440
14	530	410	650	930	1270	1800
15	650	510	800	1150	1570	2220

Table 4: Domestic Wind Turbine ouput Vs diameter and wind Speed

2.4.3 Deconstruction

Designing for deconstruction means that minimal energy need be used during deconstruction to recover materials for recycling, in addition to recovering the energy embodied in the materials, this may make a significant contribution to minimising the energy used by a building. As the majority of construction wastes actually come from deconstruction, design for deconstruction is an important consideration in building design.

(Graham, 2002)

2.5 Waste

ESD, through sustainable design, utilities principles and strategies which help reduce the environmental impact of buildings during construction, occupation and end-of useful life (i.e. a building's entire life cycle) and should be viewed as an integral part of the design process, not as an add-on or afterthought.

(Nervegna L, 2006)

2.5.1 Construction

Huge amounts of materials and energy are used in building construction (Roger, 2000). The construction process is often wasteful, although it is possible to specify low waste techniques for constructions. For example, the use of modular materials limits production of wasteful offcuts.(Birkeland, 2007) As does designing to incorporate standard product sizes and providing adequate specification to allow accurate quantity surveying (Birkeland, 2007).

It is also important to have a site management plan, detailing management procedures for all aspects of construction. In particular, Storm water handling , construction waste recycling, and soil loss management are important factors.(Environmental Protection Agency, 2008b)

2.5.2 Operations

Organic waste comprises up to 70% of household waste. And as such it is important to design with biological systems in mind in order to effectively deal with organics. (Fay , Vale & Bannister, 2004)

Conventional operational wastes can be reduced by the adage – reduce, reuse recycle; the application of these principals to conventional wastes is quite straightforward and does not merit special discussion in this project. However this approach is not traditionally applied to elements such as wastewater. As such an emphasis is placed on wastewater as an important and aspect of waste which needs to be addressed in greater detail.

In order to design the sustainable energy-waste solution for this project, an understanding of modern small-scale sustainable wastewater management techniques must be employed. Some of the most relevant technologies, from a systems standpoint, are outlined below.

Wastewater is of great importance due to the demand placed on existing supply through factors like climate change and population growth. In order to be employed for use in relieving potable water supply recycled water must be free from pathogens.(Irwin M. & Dickson A , n.d.)

Disinfection can be achieved by a number of means including chlorination, ozonation, UV irradiation and ultra-filtration. Each of which was it's own specific limitations. Some require significant pre-treatment of the water whilst other technologies have notably inefficient conversion rates (Irwin M. & Dickson A , n.d.).

HVSD – High Velocity Sonic Disinfection uses mechanical disinfection rather than chemical. This means that traditional limitations due to turbidity, TSS and other factors is overcome, therefore it does not require pretreatment. it is 100% efficient effectively treating all material that passes throughout the system, whist still maintaining valuable nutrients for return to the nutrient cycle (Irwin M. & Dickson A , n.d.). The low energy requirements and inert nutrient output makes HSVD a very attractive option from a systems perspective.

However Anaerobic Digestion has distinct advantages namely the production of energy, in the form of methane, reduction in mass of solids (60%) due to conversion, and like HVSD it is effective in the reduction of human pathogens and the sludge is stable (biologically inactive).(McFarland, 2001)

McFarland also identifies the use of domestic septage for agricultural applications is a sound practice. Although he is not referring specifically to Digester wastes, optimal levels of key indicators seem to be met by digester wastes, including but not limited to, pathogen reduction, nitrogen reduction and solids reduction.(McFarland, 2001)

Small scale commercial Biogas digesters can turn household organic wastes into Biogas. A one-cubic-meter digester, is sufficient to handle the load produced by a family of four, whilst providing enough gas to cook efficient meals thus paying for itself in savings over a two year period.(Fortune Magazine, 2008)

In addition a Biogas digester would deal with any of the remaining organic wastes that comprise 70% of household waste. The inert sludge produced by the digester also acts as a valuable fertiliser for the food production system. It is also obvious that the digesters potential to form part of the energy and nutrient systems makes it very attractive in terms of system design.

2.5.3 Deconstruction

Designing for deconstruction means that minimal energy need be used during deconstruction to recover materials for recycling, in addition to recovering the energy embodied in the materials, this may make a significant contribution to minimising the energy used by a building. As the majority of construction wastes actually come from deconstruction, design for deconstruction is an important consideration in building design (Graham, 2002).The following table presents the main principles involved in design for deconstruction, and relates them to the various possible outcome of the process.

No	Principle	Material recycling	Component remanufacture	Component reuse	Building relocation
1	Use recycled and recyclable materials	●	●	•	•
2	Minimise the number of different types of material	●	●	•	•
3	Avoid toxic and hazardous materials	●	●	•	•
4	Make inseparable subassemblies from the same material	●	●	•	•
5	Avoid secondary finishes to materials	●	●	•	•
6	Provide identification of material types	●	●	•	•
7	Minimise the number of different types of components	•	•	●	●
8	Use mechanical not chemical connections	•	●	●	●
9	Use an open building system not a closed one	•	•	●	•
10	Use modular design	•	•	●	•
11	Design to use common tools and equipment, avoid specialist plant	•	•	●	●
12	Separate the structure from the cladding for parallel disassembly	•	•	●	•
13	Provide access to all parts and connection points	•	•	●	●
14	Make components sized to suit the means of handling	•	•	●	●
15	Provide a means of handling and locating	•	•	●	●
16	Provide realistic tolerances for assembly and disassembly	•	•	●	●
17	Use a minimum number of connectors	•	•	●	●
18	Use a minimum number of different types of connectors	•	•	●	●
19	Design joints and components to withstand repeated use	•	•	●	●
20	Allow for parallel disassembly	•	•	●	•
21	Provide identification of component type	•	•	●	•
22	Use a standard structural grid for set outs	•	•	•	●
23	Use prefabrication and mass production	•	•	●	●
24	Use lightweight materials and components	●	●	●	●
25	Identify points of disassembly	•	•	●	●
26	Provide spare parts and on site storage for them and parts during disassembly	•	•	•	●
27	Retain all information of the building components and materials	•	•	•	●

Figure 9: Whole of life Design (Crowther, 2005)

2.6 Case Studies

2.6.1 CH2 – Lessons Learned

The CH2 design process incorporated many aspects of holism in it's design. It stresses the fact that by considering each component in relation to all others, and to the whole, reduces overall costs, with the team predicting favourable energy use in comparison to established benchmarks (CH2, 2006b).

The following figure shows some aspects of the human dimension which were considered as part of the holistic design process.

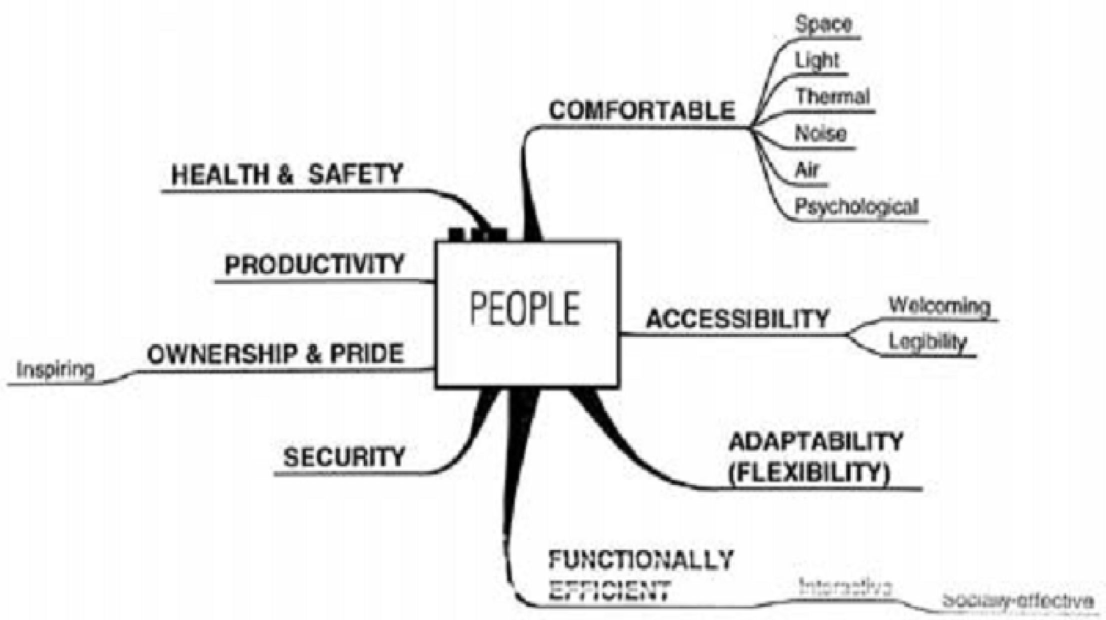


Figure 10: Holism in CH2 (CH2, 2006c)

CH2 employs a range of measures to address the different comfort levels of it's occupants. For example the thermal comfort requirements are met through a combination of passive measures and active ones such as cooled radiant ceilings and displacement ventilation, which optimise thermal comfort. (Cheung, 2006)

This synergy between active and passive systems is credited as being a direct result of the holistic design process. Aside from resulting in optimal thermal comfort of occupants, the system minimised demand on energy resulting in cost savings as well as GHG reductions.(CH2 , 2006d) Some of the main features of the design are shown in Figure 12.

The lighting comfort of CH2 occupants was achieved by the use of low energy ambient lighting as well as user controlled task lighting providing optimal level of lighting for task requirements. While passive principals were employed where possible they were largely infeasible for CH2, however all reasonable measures were taken and other aspects of holism such as the Ecological, economical and psychological and cultural issues associated with lighting were addressed (Altomonte, 2006)

Designing the energy supply for the building focused on three main strategies.

- harvesting from squander - aimed at reducing energy consumption by improving efficiency and eliminating oversupply of services;
- harvesting from waste - aimed at recovering energy that would otherwise be dissipated into the environment as waste; and
- harvesting from nature - aimed at collecting energy or an energy service from the ambient environment, and delivering it to the building occupants.

(Cheung, 2006)

Energy consumption of the building is affected by all of the previously explained principals, and is further negated by using electricity generated on site using a mix of solar, wind and gas fired co-generation power production systems. This energy is used to supply the major requirements of heating cooling and ventilation in the building. (CH2, 2006a)

Ch2s selection of materials used traditional building materials, mainly steel, concrete, glass and wood. In order to minimise the environmental effects of these materials the team specified high percentages of recycled steel and renewable timber. They also specified that concrete used for the project should achieve the following goals.

- minimise embodied energy
- minimise the content of ingredients which create greenhouse gases in their manufacture;
- maximise the use of reclaimed, recycled, waste or by-product materials;
- and minimise water use.

(CH2, 2006a)

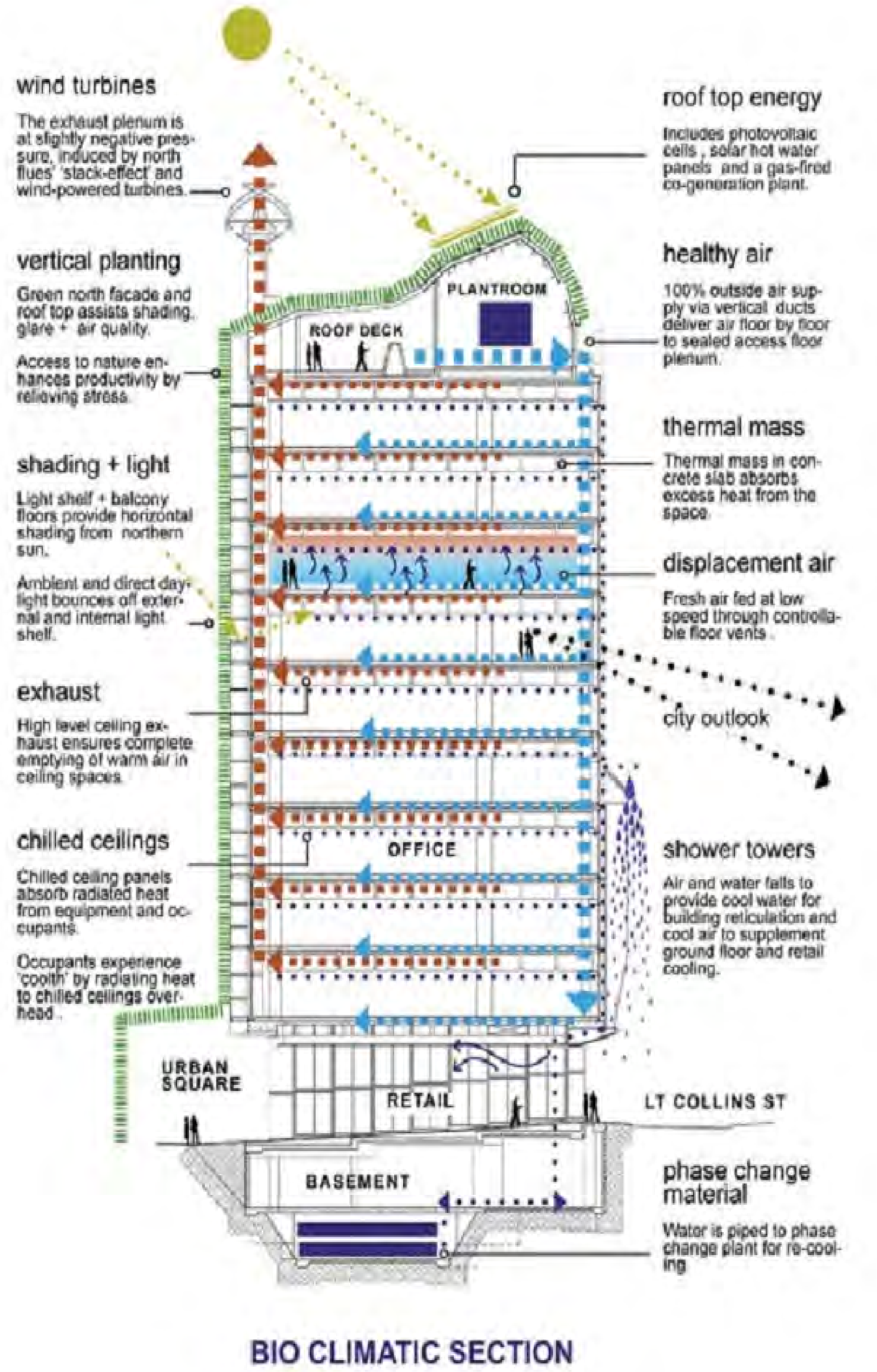


Figure 11: CH2 Design Features (CH2, 2006e)

2.6.2 CH2 – Data

Aside from the GreenStar rating given to CH2, minimal information is available on it's expected performance. This greatly hinders the opportunities for comparison with the conceptual design. There was some acceptable data relating to energy use and GHG emissions by sector, which could provide an adequate basis for analysis with this project's design.**(**Cheung, 2006)

	Overall energy consumption (kWh/m^2/year)	Overall CO2 emissions (KgCO2/m^2/year)	Lighting Power density (W/m^2)	Lighting energy consumption (kWh/m^2/year)	Cooling Energy Consumption (kWh/m^2/year)	Heating Energy Consumption (kWh/m^2/year)	Ventilation and Pump energy (kWh/m^2/year)	Office equipment (W/m^2)	Office equipment (kWh/m^2/year)
Australia									
BOMA 1994 New Building Design Target (Melbourne)	118	114	14	36	10	37	14	5	12
PCA 2001 Good Practice Benchmark (Melbourne)	186	196	15	39	17.5	47	28	n.a.	24
PCA 2001 New Building Design Target (Melbourne)	133	142	11	31	13	31	22	n.a.	15
ABGRS 5 stars		170							
UK									
Energy Consumption Guide 19: Good Practice	225	85	12	27	14	97	30	14	23
Germany									
Guidelines for sustainable building			10					25	
US CBCES	252		14*						
Hong Kong Best Practice	226								

Table 5: Office Energy Benchmarks (Cheung, 2006)

	Overall energy consumption (kWh/m²/year)	Overall CO2 emissions ($KgCO_2$/m²/year)	Lighting Power density (W/m²)	Lighting energy consumption (kWh/m²/year)	Cooling Energy Consumption (kWh/m²/year)	Heating Energy Consumption (kWh/m²/year)	Ventilation and Pump energy consumption (kWh/m²/year)	Office equipment (W/m²)	Office equipment (kWh/m²/year)
Building T-Target	100	n.a.	n.a.	25.0	13.3	6.7	n.a.	n.a.	12.5
60L - Prediction	34	n.a.	7.0	6.0	7.0	13.0	n.a.	5.0	6.0
CH_2 - Prediction	58.6	68.6	8.0	5.5	1.7	12.6	8.0	4.3	11.5

Table 6: CH2 energy use (Cheung, 2006)

Thus the overall improvements in performance attained by CH2 are calculated by comparing the predicted results with the established benchmark for existing buildings.

PCA 2001 Good Practice Benchmark (Melbourne)	186	196	15	39	17.5	47	28	5	24
CH_2 - Prediction	58.6	68.6	8	5.5	1.7	12.6	8	4.3	11.5
Percentage improvement	68.49	65	46.67	85.9	90.29	73.19	71.43	14	52.08

Table 7: CH2 Percentage Improvements

Note: As there was no benchmark established for Office Equipment Power Density in the PCA2001 Good Practice Benchmark (Melbourne), the value used in this comparison is from the BOMA 1994 New Building Design Target (Melbourne). As this is an older value it should indicate a higher % improvement, thereby providing a more challenging comparison for the evaluation of the design which is the focus of this dissertation.

2.6.3 SSHP

The Smart and Sustainable Homes program in Queensland aims to provide information on sustainable building and well as providing built examples of these techniques and technologies in various climatic regions of Queensland. Information on these buildings is available on the program's website. The SSHP website is a portal to many resources hosted by various government departments. It also provides direct advice on how to optimise green building potential. The key goals and directives outlined by the program are given below.

- refrigerator is operated using maximum efficiency
- on site electricity production- sustainably
- climate control systems to contribute to indoor air quality
- stoves and ovens are energy efficient
- optimum position of stoves and oven
- Reduced wastewater to sewer
- reduced water usage
- shading and treatment of windows-reduce heat and glare
- good roof design
- zoning for passive design
- suitable site
- site need minimal change(works) for preparation
- landscaping contributes to passive design
- termite protection does not pollute site
- efficient appliances
- efficient lighting
- efficient hot water system and supply
- efficient water supply
- reduced mains water consumption
- Potential for safe and efficient active cooling is maximised
- maximise natural ventilation to reduce need for artificial cooling
- indoor and outdoor living
- reduce energy consumption for drying clothes
- maximise daylight to reduce need for artificial light
- reduce need for artificial heating and cooling.

(Smart and Sustainable Homes Program, 2008b)

The SSHP website is hard to navigate, incoherent , and provides little information to direct users to the useful tools and information available through it's sight. Access to the program's key publications “Designing for Queensland's Climate” and “Design Objectives” was not optimised. This is unfortunate because the document is an extensive check list of design considerations relevant to many aspects of sustainability. The publication also seems to integrate a majority of the disperse information which is scattered around the websites of other government agencies. This disperse information is usually in topic specific fact sheets which make it far more difficult to assess the various aspects required in green building design.

The website itself provides updates on Mandatory building energy requirements, and includes links to many other resources, provided by other government projects and departments. This includes the “Your Home- Technical Manual”(Department of Climate Change, 2008) and many other resources used to provide the information on green building used in this report. It also provides a link to the Dept of public works- sun path diagrams which show sun paths for major centres in Queensland This is an important aid in green building design. The DIP website, accessible through the labyrinth of information on the SSHP website, also provides a postcode search which locates homes within climate zones and provides prescribed measures which should result in a minimum of a five star energy rating.(Department of Infrastructure and Planning, 2007-2009a)

Again access to these materials is not optimised and is often convoluted, in addition a majority of this information is available in the “Designing for Queensland's Climate” Publication, which further emphasizes the need to point users in the right direction. Little or no explanation is available regarding the value or proposed use of the related resources.

2.6.4 Currumbin Eco Village

The Currumbin Ecovillage is a commercial development, endorsed by SSHP. The program provides very little information on the tools or techniques used to accomplish it's goals. This is probably due to it's performance based criteria rather that prescriptive technology requirements. Despite this however, the Eco-village is a valuable example of what can be achieved by using sustainable green building principles.

The Ecovillage at Currumbin achieves:

- Self-sufficiency in energy usage and complete autonomy in water and waste water recycling
- 80% of site as open-space, 50% environmental reserve, and the same yield as standard development
- Food and material self-sufficiency through edible landscaping and streetscaping, household farming and other productive strategies

- Preservation of natural landforms and rehabilitation of the degraded site's environmental integrity
- Extensive wildlife corridors, negligible vegetation loss and extensive native plant regeneration
- Cutting edge integrated water quality measures to exemplify Water Sensitive Urban Design
- Cultural Heritage honoured and integrated
- Mix of socially-oriented innovative ecological, energy efficient housing catering for diverse needs
- On-site work strategies and facilities for village and local community
- Waste recycling strategies including an innovative RRR recycling centre
- Comprehensive traffic saving strategies to reduce vehicle impacts on and off site
- Well researched administrative framework providing social equity & enduring community integrity
- Initial and ongoing social planning to foster cohesion and promote sustainable community
- Continuing education of sustainable living and development practices via the Interpretive Centre
- Sustainable economic performance both with the development and the ongoing community

(Land Matters, 2009)

2.6.5 Gold Coast

In order to facilitate a design solution for this project further data and information was derived using gold coast specific case studies and information derived through the convoluted series of websites and information sheets which can be reached through the SSHP portal.

The Qld DIP identifies the following location constraints and design considerations which should be incorporated into buildings on, or near, the Gold Coast. The following information is taken directly (with some formatting) from the source at

<http://www.dip.qld.gov.au/sustainable-living/climate-zone-2-sub-tropical.html>

Climate zone 2: sub-tropical

Description: Warm humid summer, mild winter

Average January mean temperature: 29.4oC

Average July mean temperature: 20.4oC

Features to achieve a 5-star rating

- northern orientation for living room, with low-use rooms facing west eg. garages, bathroom and laundry
- minimise east and west facing walls and windows
- allow for good ventilation—windows and doorways able to catch breezes
- use ceiling fans and high ceilings
- use wide eaves and awnings to shade eastern and western side of house in summer, but also allows winter sun inside
- ensure roof space is well-insulated and ventilated e.g. whirlybirds and eave vents
- insulate walls
- use lighter building materials—such as timber and metal; with some denser materials for winter warmth—such as concrete and bricks
- treat sun exposed windows e.g. tinting
- when using air-conditioning, ensure room is well-insulated and sealed
- use a light coloured roof.

(Department of Infrastructure and Planning, 2007-2009a)

The Qld Dept of Public works provides sun path diagrams for the calculation of the optimal house orientation direction. The following diagram for Brisbane (closest available to Gold Coast) shows an optimal angle of approximately 21 degrees east of north.This information can accessed directly at <http://www.build.qld.gov.au/smart_housing/pdf/sp_bris.pdf>

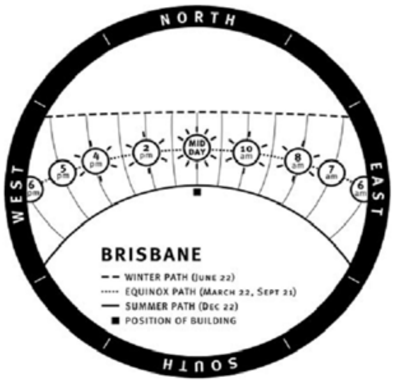


Figure 12: Brisbane Sunpath Diagram

The following wind speed data was obtained from the bureau of meteorology, in order to assess the feasibility of using domestic wind generation.

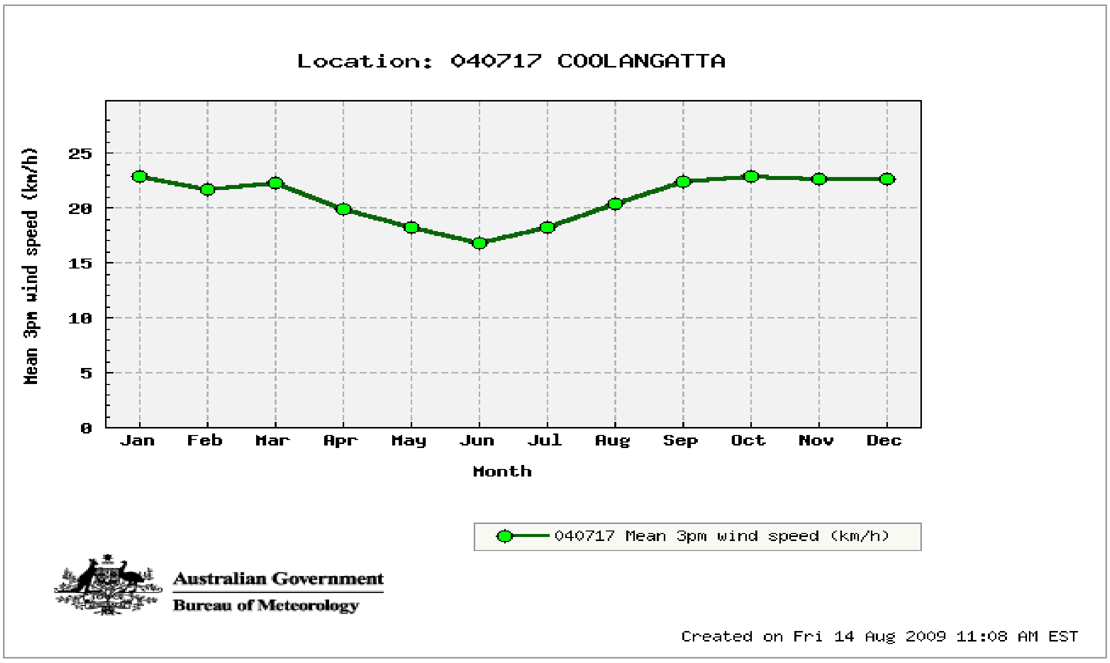


Figure 13: Mean Wind speed, Coolangata

Further information relevant to the area can be derived for the case study provided as an Appendix to this report. This case study was included in the “Your home – Technical Manual” and is presented in in part, with additional changes to spelling where required, and removal of explicit external references.

2.6.6 Solar House 1979

In 'The Conceptual Design of a Solar Heating and Cooling System for a Residential House' (George et al, 1979), the author develops a system to provide heating and cooling to a house using water heated in a solar thermal collector. While the author acknowledged the importance of systems based designs, the approach is not made explicit, much like in CH2.

One of the most important things to learn from this study is that while technologies are transient, the systems in which they are used are far less likely to change. Even the author acknowledged at the time that one of the major limitations to the design was the fact that it was designed around existing commercial technologies (George et al, 1979). As such, certain aspects such as the solar thermal collectors and heating and cooling systems used in this design are likely to be far less efficient than their modern counterparts. An alternative approach to technology based design focusses on optimising the systems design and creating technologies to support them.

The design used passive solar practices which are similar to modern practice, for the most part. Many modern designs such as those presented in Hastings & Wall (2007), are simply variations on the themes presented in this design. However, typical insulation and HVAC energy requirements of the time were used to calculate the design loads (George et al, 1979), as opposed to best practice which would require optimising these systems first. Cooling was achieved using solar heat to power a 3 ton lithium bromide adsorption chiller, with cooling tower (George et al, 1979).

The system was also designed with an automated control unit, designed to achieve a temperature set by the occupants. This practice could encourage additional energy use by neglecting the adaptive thermal comfort theory.

2.7 Analysis Techniques

Computer simulation/ building modelling is considered to be the only way to provide meaningful feedback on the effects and impacts of different design options. It is also recognised that such information only provides a basis for comparison, rather than a perfect assessment of real world performance (Bannister P, 2004)

Worldwide, there are over one hundred tools dealing with various aspects of sustainability. The aspects of sustainability included in the rating tools vary greatly as does the application to various aspects of the building life cycle (Iyer-Raniga & Wasiluk , n.d.)

As such it will be necessary to select an evaluation model that has inputs which are relevant to the design - in order to receive the most accurate appraisal. The following figures show the various aspects of industry leading tools. In order to facilitate correct choice of tool, due consideration should be given to each of these factors, as well as other constraints of the process.

Tool	Environmental performance attributes								
	Indoor environment quality				Material/Resource use				Transport
	Thermal comfort	Lighting	Air quality	Noise	Consumption	Recycle	Waste	Service life	
NABERS	✓✓✓	✓✓	✓✓✓	✓✓✓	–	–	✓✓✓	–	✓✓✓
Green Star-Office Design	✓✓	✓✓	✓✓	✓✓	–	✓✓	✓✓	–	✓✓
LCAid	–	–	–	–	✓✓✓	–	✓✓✓	✓✓	–
LCADesign	–	–	✓✓	–	✓✓	–	✓✓✓	✓✓✓	–
LISA	–	–	–	–	✓✓✓	–	–	✓✓	✓✓
EPGB	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
BASIX	✓✓	✓✓	–	–	–	–	–	–	–
Firstrate	✓✓✓	–	–	–	–	–	–	–	–
NatHERS	✓✓✓	–	–	–	–	–	–	–	–
AccuRate	✓✓✓	–	–	–	–	–	–	–	–
BERS	✓✓✓	–	–	–	–	–	–	–	–
ABGR	–	–	–	–	–	–	–	–	–
EcoSpecifier	✓✓	–	✓✓✓	–	✓✓	✓✓✓	✓✓✓	✓✓✓	–
Evergen Product Guide	–	–	✓	–	–	✓	✓	✓	–
GBTool	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓	✓✓✓	✓	✓✓
BREEAM	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	–	–	✓✓
Green Globes	✓✓	✓✓	✓✓	✓✓	–	✓✓	✓✓	–	✓✓
LEED	✓✓	–	✓✓	–	–	✓✓	✓✓	–	✓✓
CASBEE	✓✓	✓✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓
ENVEST	–	–	–	–	–	–	✓	✓✓	–
ATHENA	–	–	–	–	✓✓✓	–	✓✓✓	–	✓✓
ECO-QUANTUM	–	–	–	–	✓✓	–	✓✓	✓✓	–
ECOPROFILE	✓✓	✓✓	✓✓	✓✓	✓✓	–	✓	–	✓✓
BEAT	–	–	–	–	–	–	✓✓	–	–
GreenCalc	–	–	–	–	✓✓	–	–	–	✓✓
BEES	–	–	✓✓✓	–	–	–	–	–	–
EQUER	–	–	–	–	–	–	✓✓✓	–	–

Figure 14: Rating tools (Iyer-Raniga & Wasiluk , n.d.)

Tool	Environmental performance attributes								
	Energy					Water			
	Embodied energy	Operation	Efficiency	Thermal load	Renewable	Embodied water	Operation	Efficiency	Reuse
NABERS	–	✓✓	–	–	–	–	✓✓	–	–
Green Star-Office Design	–	✓✓	✓✓	–	–	–	✓✓	✓✓	–
LCAid	–	✓✓	–	–	–	✓✓	✓✓	–	–
LCADesign	✓✓✓	✓	✓	–	–	✓✓✓	✓	✓	–
LISA	✓✓	✓✓	–	–	–	✓✓	✓✓	–	–
EPGB	✓✓	✓✓	✓✓	✓	✓	–	✓✓	✓✓	✓✓
BASIX	–	✓✓	✓✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓
Firstrate	–	–	✓✓✓✓	–	–	–	–	–	–
NatHERS	–	–	✓✓✓✓	–	–	–	–	–	–
AccuRate	–	✓✓	✓✓✓✓	✓✓✓✓	–	–	–	–	–
BERS	–	–	✓✓✓✓	–	–	–	–	–	–
ABGR	–	✓✓✓	✓✓	–	–	–	–	–	–
EcoSpecifier	✓✓	✓✓	✓✓✓	✓	✓✓✓	–	✓✓	✓✓✓	✓✓
Evergen Product Guide	✓✓	–	–	–	–	✓	–	–	–
GBTool	✓✓	✓✓	✓✓✓	–	✓✓	–	✓✓	✓✓	–
BREEAM	–	✓✓	✓✓	–	–	–	✓✓	✓✓	–
Green Globes	–	✓✓	✓✓	–	–	–	✓✓	✓✓	–
LEED	–	–	✓✓	–	✓✓	–	–	✓✓	–
CASBEE	–	✓✓	✓✓	✓✓	–	–	–	✓✓	–
ENVEST	–	✓✓	✓	✓	–	–	–	✓	–
ATHENA	✓✓✓	–	–	–	–	–	–	–	–
ECO-QUANTUM	–	✓✓	–	–	–	–	–	–	–
ECOPROFILE	–	✓✓	–	–	–	–	✓✓	✓	–
BEAT	–	✓✓	–	–	–	–	✓✓	–	–
GreenCalc	–	✓✓	–	–	–	–	✓✓	–	–
BEES	✓✓	–	–	–	–	✓✓	–	–	–
EQUER	–	✓✓	–	–	–	–	✓✓	–	–

Figure 15: Rating tools (Iyer-Raniga & Wasiluk , n.d.)

Tools	Environmental Performance Attributes										
	Environment Impact										
	Global warming	Ozone depletion	Acidification	Eutrophication	Human toxicity	Ecotoxicity	Winter/ summer smog	Emission to air	Emission to water	Emission to land	Biodiversity
NABERS	✓✓✓	✓✓	–	–	–	–	–	–	✓✓	–	✓✓
Green Star- Office Design	✓✓	✓✓	–	–	–	–	–	–	✓✓	–	✓✓
LCAid	✓✓	✓✓	✓✓	✓✓	✓✓	–	✓✓	✓✓	✓✓	✓✓	–
LCADesign	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓	–
LISA	✓✓	–	–	–	–	–	–	✓	–	–	–
EPGB	✓✓	✓✓	–	–	–	–	–	✓✓	✓✓	✓✓	✓✓
BASIX	✓✓	–	–	–	–	✓✓	–	✓	✓	✓	–
Firstrate	–	–	–	–	–	–	–	–	–	–	–
NatHERS	–	–	–	–	–	–	–	–	–	–	–
AccuRate	–	–	–	–	–	–	–	–	–	–	–
BERS	–	–	–	–	–	–	–	–	–	–	–
ABGR	–	–	–	–	–	–	–	–	–	–	–
EcoSpecifier	✓✓	✓✓	–	–	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓
Evergen Product Guide	✓	✓	–	–	–	–	–	✓	✓	✓	✓
GBTool	✓✓✓	✓✓✓	✓✓	✓	–	–	✓	–	✓✓	–	–
BREEAM	✓✓	✓✓	–	–	✓✓	✓✓	–	✓	–	–	✓
Green Globes	✓	✓	–	–	–	–	–	✓	✓	–	–
LEED	✓	✓	–	–	–	–	–	–	–	–	✓
CASBEE	–	–	–	–	–	–	–	✓✓	✓✓	✓✓	–
ENVEST	✓	✓	✓	–	✓	✓	–	✓	✓	–	–
ATHENA	✓✓✓	–	–	–	–	–	–	✓✓	✓✓	–	–
ECO-QUANTUM	–	–	–	–	–	–	–	✓✓	✓✓	–	–
ECOPROFILE	–	–	–	–	–	–	–	✓✓	✓✓	✓✓	✓✓
BEAT	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	–	–	–	–
GreenCalc	–	–	–	–	–	–	–	–	–	–	–
BEES	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	–	–	–	–	–
EQUER	✓✓	–	✓✓	✓✓	✓✓	✓✓	✓✓	–	–	–	–

Figure 16: Rating Tools (Iyer-Raniga & Wasiluk , n.d.)

2.7.1 Basix

Basix is one of the last free, Australian government endorsed assessment programs. In addition to this it's relative ease of use allows simple assessment of reductions in emissions and water requirements for residential buildings.

The main output of basix is a certificate of compliance showing that minimum reductions in water use and greenhouse emissions have been met, using state averages as a benchmark. The analysis process also provides the predicted percentage reduction in these measures (Basix, 2008).

This would allow easy comparison with the data provided by CH2. Which is a major consideration as the data provided is minimal, limiting options for comparison.

2.7.2 GreenStars

The GreenStar Rating Technique, administered by the GBCA, provides a star rating to buildings based on their performance across different aspects of environmental impact. Different tools exist to analyse different kinds of building, such as offices or multi unit residential.

Rating	Required Score	Comment
One Star	10	
Two Star	20	
Three Star	30	
Four Star	45	Best Practice
Five Star	60	Australian Excellence
Six Star	75	World Leader

Figure 17: GreenStar Rating System (James P, 2004)

The GreenStar Multi Residential tool has many assessment items in common with other GreenStar rating tools, however special consideration has been given to the unique characteristics of residential buildings and this is reflected in the differing assessment items (Green Building Council of Australia, 2009).

Although the details analysed and their relative weighting varies between tools, each different type of building is assessed on the following areas, which are comprised of the individual assessment items.

- Transport
- Water
- Materials
- Land use and ecology
- Emissions
- Innovation Management
- Indoor Environment Quality (IEQ)
- Energy

(James P, 2004)

The scores for individual aspects are rated according to the relative importance of the categories above, and the weighted score is used to determine a GreenStar rating. (James P, 2004) The GreenStar tool also provides an input for Basix assessments to determine components of the energy score. This provides the potential for additional assessment of the design, without duplicating unnecessary work.

3.0 Methodology

Both the design and assessment of the project will be focussed around maximising energy improvements for the design, and assessing the design's potential to achieve a green star rating. Additional comparison will also be made with raw data given by CH2, to compare the energy improvements across various fields common to both designs.

3.1 Rationale: Design

In order to design a sustainable Energy-waste solution for a residential house it is first necessary to know the design constraints that need to be met by the system. One must know the amount of energy and waste that needs to be supplied/disposed in order to determine the demand that will be placed on the technologies involved.

Sustainability demands that the inputs and outputs of a given system are kept to a level that can be sustained ad infinitum by the environment in which that system operates. Thus, in order to truly be sustainable such a system must be designed to provide for the specific needs of residents, and must use the minimum possible energy and materials to do so.

Shortly after beginning the literature review, it was evident that the fundamental principals of sustainability and green building do not allow the design of an energy-waste solution in-vacuo.

Green building principals demand an integrated systems design, to ensure that the house as a whole is sustainable. This also allows the various inputs and output of systems within the house to be met by other systems within the house, thus reducing demand on all participating systems and their operating environments.

The application of this is that an energy and waste solution designed to deal with the needs of a standard residential house may still be unsustainable as the demand generated by poor house design is still in excess of environmental limits. It is the related systems of the house which generate demand, and can often meet it.

As such the design of an energy-waste solution will be incorporated into the design of a theoretical sustainable house designed to embody Green building principles and reduce demand on the Energy-waste system.

3.2 Process: Design

The information from SSHP was used to create a base design for a sustainable green building. The primary features in this design, as identified by the literature were –

- House orientation
- Zoning and location of rooms
- Window size and Placement
- Window Glazing
- Overhang of eaves
- Building materials (where necessary)

This design was assessed using the Basix assessment system. The initial model adopted none of the recommended technologies or additional design features recommended by Basix. Of particular note it included electric cooking facilities and hotwater systems. This allowed the first model to assess the reduction in load due solely to the passive design of the building.

The second model included recommended technologies and additional features recommended by the Basix assessment. Primary among these were a Gas boosted solar hot water system, and dedicated use of Compact fluorescent lights, as well as gas cooking. An extensive list of additional design features is given in the results section.

Several models were then undertaken using different amount of renewable energy in order to supplement the remaining energy load. This was done in order to provide a selection of reasonable Basix values for input into the GreenStar system in the next stage of analysis.

During the assessment process, there are certain prescriptions which must be met in order to achieve optimal ratings. The assessment systems also incorporate several aspects of building fitout and operation which are not included in the basic passive design, though they must be assessed in order to achieve a rating. In these cases, prescriptions were assumed to have been met and assessable features were assumed to achieve the best performance that could be reasonably expected for the specific circumstances. Details are made apparent in the Basix and GreenStar assessment results.

3.3 Rationale: Comparison

The conceptual nature of the design means that major portions of the performance must be assessed in terms of design techniques as well as the types of technologies involved rather than their specific performance. Where specific performance ratings are required these are usually assumed to be the most efficient / best performance which can be reasonably expected of the specified technology/design measure. For example, maximum efficiency solar hot water, fittings and appliances are assumed as these measures are cost effective means of reducing energy requirements. Basix and GreenStar will be used for the Energy comparison as Basix provides a means of assessing more general design parameters whilst GreenStar provides a means of direct comparison with CH2.

3.4 Energy Comparison

The Basix program will be used to determine the % reduction of GHG emissions; this can then be directly compared with the data provided by CH2. Additional data was kindly provided by the Basix team in order to facilitate greater comparison between the design and CH2.

The GreenStar system will also be used as it offers a direct comparison. The multi unit tool will be used to assess applicable aspects of the design. The process of determining the target score is given in this diagram.

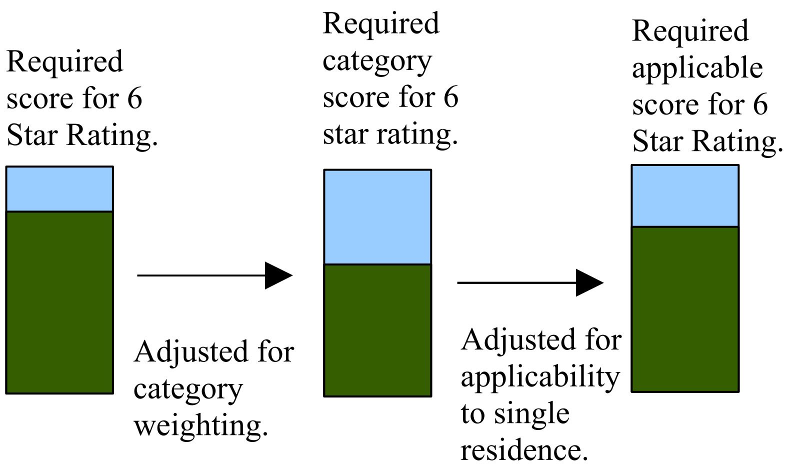


Figure 18: Comparison Methodology

This may provide a more accurate comparison as the GreenStar system places a different emphasis on energy and waste between office and residential sectors. As such, the same % reduction in GHG emissions may result in a different GreenStar rating, depending on building type.

In application however, all of the criterion were included in the design assessment. This is because there is the potential for such measures to be used in single family residences, even though they are more suited to multiple residencies.

Where rating tools cannot provide an accurate assessment of the design benefits, due to factors such as unlisted technologies and complex nature of system design, a comparison model may be derived using information from the literature to determine the magnitude of typical improvements which would be made by employing such technologies. Any required information not presented in the literature review would be sourced form similar sources as the material covered.

Such an approach is highly unscientific but may serve to illustrate the unrecognised improvements achieved by the conceptual design. It should not be considered as an accurate prediction of system performance.

Additional assessment problems also exist with using the Basix system to assess the design.

- no option for straw bale
- does not account for shading due to car port,
- buffering due to foyer,
- cannot account for lifestyle,

3.5 Waste Design & Comparison

The lack of information from CH2 as well as scarcity of data for residential benchmarks presents real problems for the waste comparison of the design. From the information given on the available rating tools, five major tools have components dealing specifically with waste. These are NABERS, Green Star, LCAid, LCA Design, EPGB and Eco Specifier.

EcoSpecifier is a high cost subscription service, NABERS assesses actual waste quantities rather than design features as does EPGB. Of the remaining, GreenStar once again presents the best alternative because of the ease of comparison between the design results and the rating from CH2. While the applicability of waste aspects differs greatly between offices and residential buildings, the goal would be to achieve a score which would contribute the relevant share towards a 6 GreenStar rating.

Unfortunately, the various aspects of waste are incorporated under different sections of the assessment process. The level of detail required is also beyond the scope of this design. As such, grey water will be used for non-potable uses through the site and wastewater will be assumed to be recycled in a domestic methane digester. The gas from the digester will be used to fuel the cooking needs of the household, further reducing demand. Any surplus gas could be used for water or space heating (if required) to prevent excessive build-up.

Other forms of operational waste, such as those associated with packaging, will be mitigated using a standard strategy of “reduce, re-use, and recycle”. A large portion of this strategy relies on occupant behaviour and lifestyle and is therefore very difficult to quantify and improve upon. On site food production is one way of drastically reducing packaging and transport costs.

3.6 Meeting Renewable Energy Targets

Having determined the Basix scores required to achieve a six star rating it was easy to determine the additional renewable energy which was needed in order for the design to achieve that score.

The literature identifies a range of renewable technologies which could be incorporated into the design. These are then considered for their suitability for meeting the load, as well as their suitability for the site constraints and their overall harmony with the systems of the design.

4.0 Results

4.1 Design

The House design was developed by taking the recommendations of the SSHP and other green building resources and using them to design the basic structure of the house. The Basix rating system was then used to assess the base design. When needed additional features & fitout were added to ensure Basix compliance and optimal energy reductions. Additional features were also added by the same procedure during the GreenStar assessment.

The Base Design which was developed for this project was based on the recommendations of SSHP, and other key green building resources. The Layout of the house is shown in the following pages.

- Size –A size of 300sq.m was used In accordance with current housing data (ABS 2006), which specifies this as the average new home size.
- Materials – Traditional materials were used for a majority of the design. While materials data from the literature suggests Straw Bale to be an ideal material for the design climate, it was unable to be assessed by the Basix rating system. Instead an Insulated External Façade System (EIFS) was used. This gave highly insulative values, though it's other credentials as a green building material are debatable.
- A window height of 1m was used.
- Eaves > 0.5m were used particularly on highly exposed areas.
- Rooms were zoned for usage compatibility
- The house was oriented at an angle 21 degrees east of north. For the Basix assessment, a northerly aspect was specified.
- The north facing area was maximised, and westerly exposure minimised. Thus there is an elongated east-west axis.
- High use rooms were located with access to daylighting and winter sun (northern exposure).
- A car port was included on the western side of the house to shade the western end of the house without using high-end building materials used for the main house.

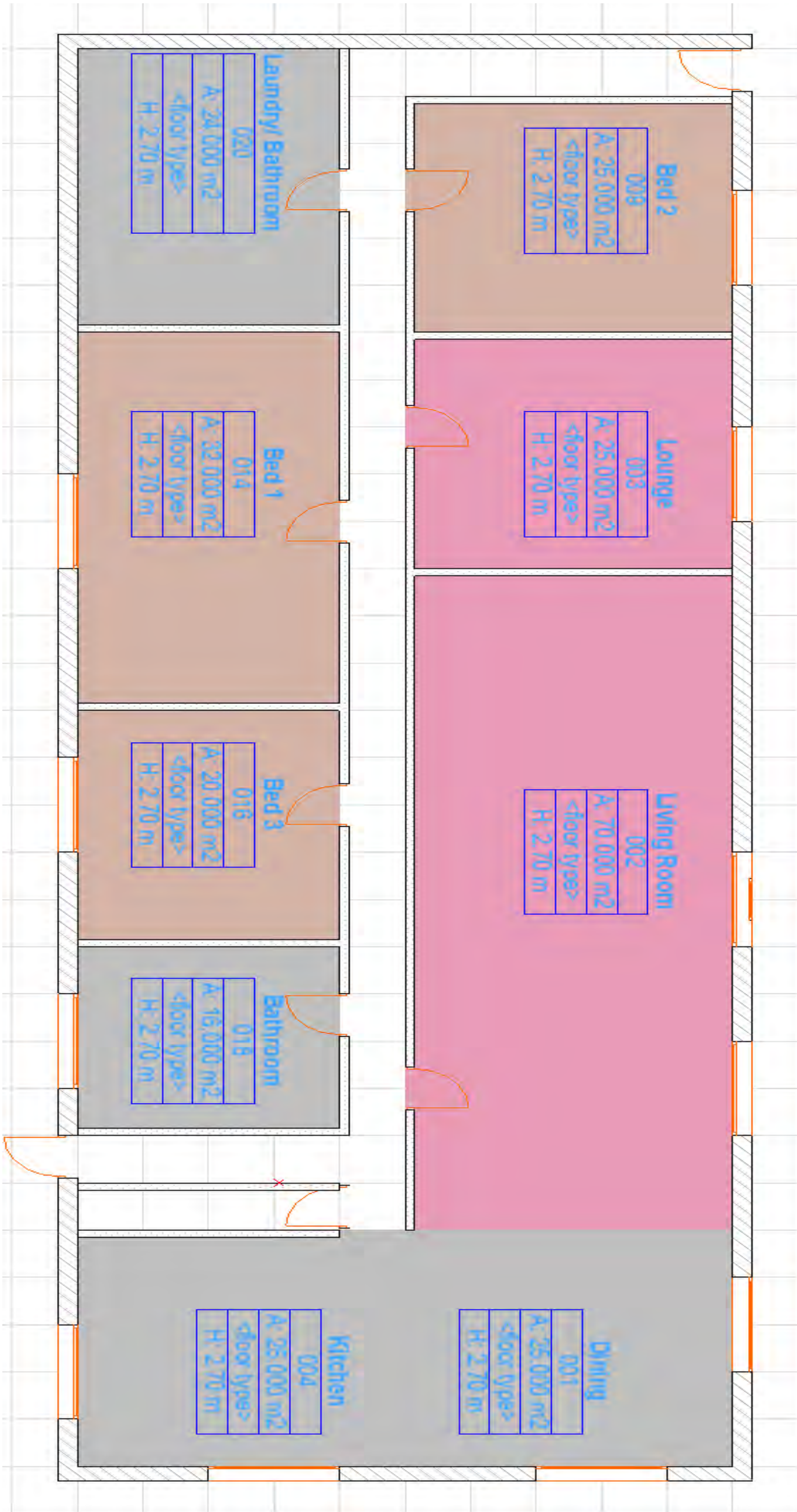


Figure 19: Design Floor Plan

4.2 Basix Results

The base house as specified above was the first model which was assessed using Basix. In the second model additional features were derived from the Basix assessment processes and recommendations, which required additional specification not yet included in the design. These features were incorporated into the design in order to achieve maximal ratings.

The remainder of the models assessed the Basix score achieved if differing proportions of the remaining demand was met by renewable energy. The results for all models are given below.

Peak kW renewable energy	Score
0 (Base Building only)	13%
0 (Improved fitout and features)	61.00%
1	78.00%
1.5	86.00%
2	94.00%
2.5	103.00%

Table 8: Basix Results for various models

4.2.1 Additional features derived from Basix

Results for the initial model did not meet the minimum standards for Basix certification. As such, Basix recommends a list of design features which can be modified to improve building performance. A copy of the recommendations follows.

Tips on passing energy

Hot water

Hot water is contributing 37% to your greenhouse gas emissions for the project.

Heating and Cooling

Cooling is contributing 5% to your greenhouse gas emissions for the project.

BASIX does not regard 'no active cooling' for your living areas as being realistic for your home as it is currently designed, and will assume that the occupants will install a low efficiency air-conditioner. Return to Thermal Comfort and improve the design of *your home to reduce your cooling load, or else install an efficient cooling system to improve your energy score.*

Heating is contributing 4% to your greenhouse gas emissions for the project.

Lighting

Lighting is contributing 15% to your greenhouse gas emissions for the project.

Nominating rooms that are primarily lit by fluorescent lighting may improve your energy score.

Other

Cooking is contributing 7% to your greenhouse gas emissions for the project. Note that other uses (such as electrical appliances) make up 32% of your greenhouse gas emissions for the project.

If you have gas available you could select a more efficient cook top & oven (Options at the top of the cooktop & oven drop down lists are the most efficient)

The full list of details, as assessed by Basix, including those adopted following Basix recommendations, is included as an appendix to the dissertation. The same configuration of options was used for all models except the initial base building model. As has been mentioned the only variation after this was the increased amount of renewable energy which was adopted by the house.

4.3 GreenStar Results

The GreenStar Multi unit residential rating assessment calculator uses the following weighted categories to determine the relative importance of various aspects of building design.

Category Weightings	
Management	8%
IEQ	20%
Energy	25%
Transport	10%
Water	15%
Materials	10%
Land Use & Ecology	7%
Emissions	5%
TOTAL:	100%

Figure 20: Green Star Weightings

As such, the energy rating contributes 25% to the overall score of the building. Thus, in order to achieve a Six Star score of > 75 points, the energy components must contribute 18.75 weighted points to the overall score.

The Basix score required to achieve this target is also given, for the different conditions assumed under each model.

Case	Weighted Score	Un-weighted	Basix Req.
1	20	18	79
2	18	17	79
3	18	17	86
4	21	19	94
5	14	13	61

Table 9: GreenStar requirements for 6-Star rating

Case 1
All additional (non-Basix score) options within the GreenStar tool were maximised. This allowed a lower Basix score to achieve the desired Target.

Case 2
Cautious values were used for additional options; this involved selecting a lower (50%) value for one of the 3 options. This resulted in an unacceptable weighted score.

Case 3
Cautious values were used for all of the additional assessment criteria, and additional renewable energy (1.5kW system) was included in the Basix assessment. This still resulted in an unacceptable weighted score.

Case 4
Cautious values were used for all of the additional assessment criteria, and additional renewable energy (2kW system) was included in the Basix assessment. This resulted in an acceptable weighted score.

Case 5
This case examines the house without any additional renewable energy inputs. It assumes optimal values for all additional criteria. It clearly fails to achieve a satisfactory weighted score.

4.4 Energy Deficit.

From the above results it is easy to see that the building can achieve a six-GreenStar equivalent rating if it achieves a Basix rating of >79%. Of the options modelled earlier the one kilowatt system achieves 78% reductions which is incredibly close to the desired outcome of 79%. The next successful option is the 1.5kW option which achieves a Basix score of 86% reduction This is far in excess of the requirements for a six star rating, however it is likely to be the first acceptable solution available as a commercial product. While a system of 1.05-1.1kW would also have given an acceptable solution it is likely to be difficult to source as a commercial product.

Thus, a six-GreenStar rating is achievable for a residential house using just a 1.5kw (peak) renewable system. In order to attain full self-sufficiency for the building it is necessary to use a 2.5 kW system.

4.5 Energy Supply

While there is a broad range of renewable energy technologies available to supplement domestic supply, there were a few which were identified in the literature review as being the most promising.

Of these the Domestic CHP is more suited to cooler regions, the relative demand for heat and electrical energy of the 3:1 – heat: electrical output produced by the system.

The meteorological data shows that the mean wind speed for the area in insufficient to make wind turbines viable.

Solar Photovoltaic systems are identified as being the ideal candidate for the design. If a 1 kW system was installed, then the house would need to remain connected to the mains supply grid. If the 2.5 kW system were installed, grid connection would result in a small income stream. A stand alone (non-grid connect) system at 2.5 or possibly 2 kW could force occupants to adapt their lifestyle to one which induced greater savings.

4.6 Waste

As mentioned in the methodology wastewater will be assumed to be recycled in a domestic methane digester. The gas from the digester will be used to fuel the cooking needs of the household, further reducing demand. Any surplus gas could be used for water or space heating (if required) to prevent excessive build-up.

Other forms of operational waste, such as those associated with packaging, will be mitigated using a standard strategy of "reduce, re-use, and recycle". A large portion of this strategy relies on occupant behaviour and lifestyle and is therefore very difficult to quantify and improve upon. On site food production is one way of drastically reducing packaging and transport costs.

4.5 Comparison

As has been mentioned several times throughout this dissertation, the basis of comparison between the house design and CH2 is incredibly complex. Due to the limited information available on CH2 there are only a few aspects which are available for comparison. The two main areas for comparison are of course the GreenStar Rating achieved by each building and the % GHG reduction each building achieves.

The GHG reductions for the design were calculated by Basix, and can be considered conservative as they use market average values for appliance energy use etc. The following figure is an indication of the percentage Greenhouse Gas reductions which were achieved by various designs involved in the project.

The green entry shows the % reduction required in order to achieve a 6-GreenStar design (79%). The yellow entry shows the % reduction achieved by installing a 1kW peak renewable energy system(78%). While this is slightly less than that required in order to achieve a 6 star rating, it is significantly greater than that achieved by the CH2 building.

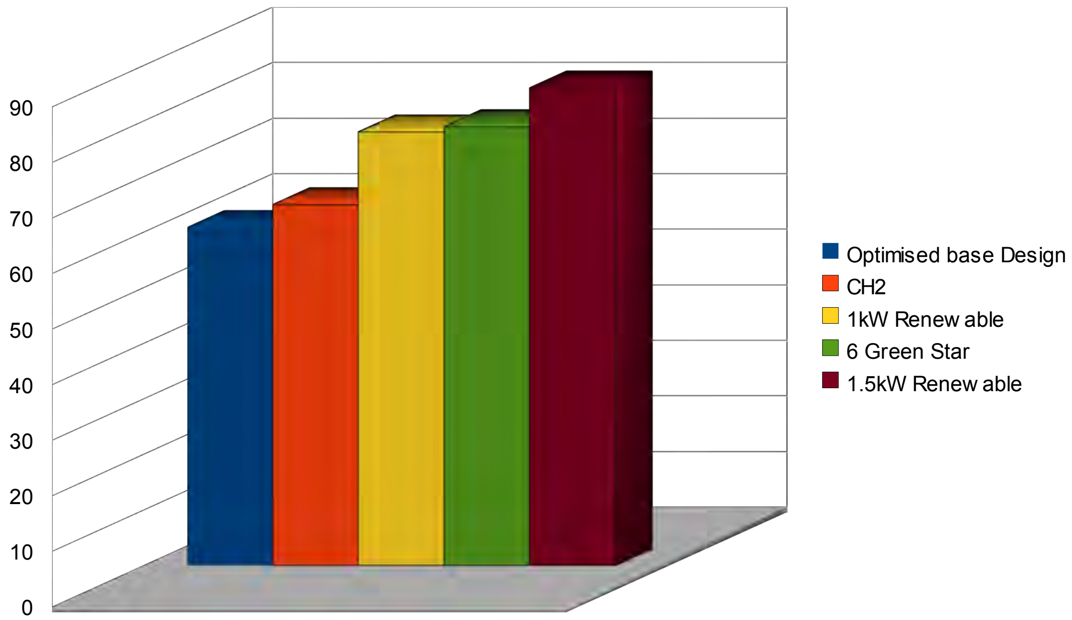


Figure 21: Comparison of GHG reductions between models

The optimised base design fails to achieve any of the major benchmarks, except surpassing the Basix requirements for minimum energy reduction required of new buildings.

The first design to surpass all benchmarks was the 1.5kW renewable energy system.

Due to the methodology employed during the design process, the design achieves a 6 star rating (using the Multi-unit residential Pilot). Although there is no GreenStar rating tool specifically tailored to single residence domestic dwellings, there is a sound basis for admitting that the design has achieved a six-GreenStar rating. As such, a comparison of the ratings achieved by the designs shows that it is possible, and easily achievable, for a residential house to achieve the same level of sustainability as large commercial buildings.

5.0 Conclusions

This project has resulted in outcomes far beyond the initial project brief. The design of the energy and waste solution was found to be inextricably linked with the house as a whole. As such, it is clear that the design and optimisation of energy and waste solutions are predicated on an understanding of the interconnected nature of energy systems. This necessitates an Holistic approach which seeks to mitigate and manage demand in order to provide supply more sustainably.

The project successfully delivered a conceptual design for a three bedroom residential house and determined the potential for massive reductions in energy demand, and the associated greenhouse gasses.

The project also successfully showed the ease with which a residential house can achieve the equivalent of six-GreenStar status. By incorporating an understanding of the site under consideration, as well as potential for integration with other housing systems, an energy and waste solution was selected which ensured a six star rating.

5.1 Further Work

While the decision making matrix did not come to fruition during this project, it was realised that the generic nature of such a paradigm would be unsuited to the requirements for specific, case specific, information.

A more suitable alternative would be the automation of the design process. Ideally, by selecting a location and house size, specific design features would be determined from the literature. These would include materials, orientation, location of rooms, shading requirements etc. based on the climate zone of the location. Design load could then be calculated, and meteorological data for the region assessed and the best technologies selected. Design could be integrated with existing CAD packages to allow real-time assessment to design changes as requested.

Although this is a time of great technological focus on environmental issues, with great innovation and breakthroughs in many areas, this project shows that the knowlegs and technology exists at present to ***drastically*** reduce our impact on the environment. As such, the largest part of the the future work will be done by the the people who demand a new era in building, the industry that provides it, and the regulators who ensure it.

6.0 REFERENCES

GOVERNMENT PAPERS

Dept of Env 2008,“Cool it – Households” (accessed 15/4/9) <http://www.environment.gov.au/settlements/gwci/households.html>

Department of Infrastructure and Planning 2007-2009a “Improving sustainable housing in Queensland - Postcode search” (accessed 15/4/9) <http://www.dip.qld.gov.au/sustainable-living/climate-zone-2-sub-tropical.html>

Department of Infrastructure and Planning 2007-2009b “Improving sustainable housing in Queensland”, (accessed 15/4/9) <http://www.dip.qld.gov.au/sustainable-living/improving-sustainable-housing-in-queensland.html>

Smart and Sustainable Homes Program 2008a “Ten Tips for sustainable housing”,, (accessed 15/4/9) <http://www.sustainable-homes.org.au/02_design/ten.htm>

Smart and Sustainable Homes Program 2008b “Design Objectives”- (accessed 15/4/9) <http://www.sustainable-homes.org.au>

Environmental Protection Agency 2008a “Energy Efficient Home Design” (accessed 15/4/9) <www.epa.qld.gov.au/sustainable_industries>

Environmental Protection Agency 2008b “Fact Sheet: Sustainable Housing” (accessed 15/4/9) <www.epa.qld.gov.au/sustainable_industries>

Department of Public Works 2008 “Qld climate zones map” (accessed 15/4/9) <http://www.build.qld.gov.au/smart_housing/pdf/climate_zones_map.pdf>

Department of Climate Change 2008 “Your Home- Technical Manual” (accessed 15/4/9) **<http://www.climatechange.gov.au/resources/community.html#building>**

Building council of Australia (n.d) - “Energy use Star Bands”, (accessed 15/4/9)

Land Matters Pty Ltd. 2009 “Executive Summary – The Eco-Village at Currumbin” (accessed 15/4/9) <www.theecovillage.com.au>

Qld Dept Health & Aging 2002- "Healthy Homes",(accessed 15/4/9) <http://www.nphp.gov.au/enhealth/council/pubs/pdf/healthyhomes.pdf>

BDEP PAPERS

Institution of Engineers (1999) "Engineers Australia Policy on Sustainability" - Gen 27 (accessed 15/4/9) <www.environmentdesignguide.net.au>

RAIA (2001) "RAIA ENVIRONMENT POLICY" -Gen 01
(accessed 15/4/9) <www.environmentdesignguide.net.au>

Bannister P (2004). "DESIGNING BUILDINGS THAT ACTUALLY PERFORM"
-GEN 65
(accessed 15/4/9) <www.environmentdesignguide.net.au>

Luther M & de Dear R (2003) "APPLYING THE ADAPTIVE MODEL OF COMFORT" -Des 57 (accessed 15/4/9) <www.environmentdesignguide.net.au>

Wall C (2000) "An approach to Integrated Systems Design" - Des 36
(accessed 15/4/9) <www.environmentdesignguide.net.au>

Iyer-Raniga U & Wasiluk K. (n.d.) "Sustainability Rating Tools" -Des 70
(accessed 15/4/9) <www.environmentdesignguide.net.au>

Engwicht D (2003) "MENTAL LANDSCAPES – THE FORGOTTEN ELEMENT IN SUSTAINABLE DESIGN"- Gen 55 (accessed 15/4/9)
<www.environmentdesignguide.net.au>

Vale B & R (2003) "URBAN AUTONOMOUS SERVICING" - Gen18 (accessed 15/4/9) <www.environmentdesignguide.net.au>

Prasad D & Fox E (2001) "RENEWABLE RESOURCES ENERGY GENERATION" - Des 10 (accessed 15/4/9)
<www.environmentdesignguide.net.au>

Crowther P (2005) "DESIGN FOR DISASSEMBLY" - Des 31 (accessed 15/4/9)
<www.environmentdesignguide.net.au>

Nervegna L (2006)"Sustainable Design" -Des 5
(accessed 15/4/9) <www.environmentdesignguide.net.au>

Rodger, A (2000) "ENVIRONMENTAL DESIGN AND ARCHITECTURE" - Gen 2
(accessed 15/4/9) <www.environmentdesignguide.net.au>

Treloar G & Fay R (2005) "BUILDING MATERIALS SELECTION :GREENHOUSE STRATEGIES" - Des 35 (accessed 15/4/9)
<www.environmentdesignguide.net.au>

Graham P (2002) “WASTE MINIMISATION – SOURCE REDUCTION” - Tec 01 (accessed 15/4/9) <www.environmentdesignguide.net.au>

Birkeland J.(2007) “Ecological Waste: Rethinking the Nature of Waste” - Gen 6, (accessed 15/4/9) <www.environmentdesignguide.net.au>

Fay R, Vale R & Bannister P. (2004) “NABERS” -Gen 56 (accessed 15/4/9) <www.environmentdesignguide.net.au>

James P (2004) “GreenStar: a users Perspective” - GEN 63 (accessed 15/4/9) <www.environmentdesignguide.net.au>

CH2 PAPERS

CH2 (2006a) “The Building Structure and the Process of Building” (accessed 15/4/9) http://www.melbourne.vic.gov.au/info.cfm?top=171&pg=1933

CH2 (2006b) “Energy”   Summary paper 6 (accessed 15/4/9) http://www.melbourne.vic.gov.au/info.cfm?top=171&pg=1933

CH2 (2006c) “Workplace Environment” - Summary paper 2 (accessed 15/4/9) http://www.melbourne.vic.gov.au/info.cfm?top=171&pg=1933

CH2 (2006d) “Heating and Cooling System” – Summary paper 5 (accessed 15/4/9) http://www.melbourne.vic.gov.au/info.cfm?top=171&pg=1933

CH2 (2006e) “Lighting and Physiology” - Summary paper 3 (accessed 15/4/9) http://www.melbourne.vic.gov.au/info.cfm?top=171&pg=1933

Cheung C.K. (2006) “Energy Harvesting Systems: Economic Use and Efficiency” CH2 - Tech paper 6, (accessed 15/4/9)

http://www.melbourne.vic.gov.au/info.cfm?top=171&pg=1933

Altomonte S, (2006) “Lighting and Physiology: Artificial and natural lighting and its relation to the human body”, CH2 - Tech paper 3, (accessed 15/4/9) http://www.melbourne.vic.gov.au/info.cfm?top=171&pg=1933

RATINGS METHODS

Basix (2008) “Basix: Fact Sheet” (accessed 15/4/9) www.basix.nsw.gov.au

Green Building Council of Australia 2009 "RATING TOOL FACT SHEET: GREEN STAR MULTI UNIT RESIDENTIAL" (accessed 15/4/9) www.gbca.org.au

SUNDRY

"ENGINEERS AUSTRALIA POLICY ON SUSTAINABILITY"- BDEP Gen 27 (accessed 15/4/9) www.environmentdesignguide.net.au

The Rocky Mountain Institute 2009 "Why build Green?" (accessed 15/4/9) www.rmi.org

Miller P (2009), "Saving Energy: It starts at home" *National Geographic'* March 2009

ABS (2006) "Environmental Impact of Household Energy Use" - 4102.0 - Australian Social Trends, (accessed 15/4/9) www.abs.gov.au

Fortune Magazine (27/2/08) "Waste not, want not" (accessed 15/4/9)

http://money.cnn.com/magazines/fortune/fortune500/2008/

Low Impact Living Institute (n.d) - "Biogas", (accessed 15/4/9) www.lowimpact.org/factsheet**biogas.pdf**

Irwin M. & Dickson A (n.d.) "High Velocity Sonic Disintegration"., (accessed 15/4/9) http://www.ipweanswconference.com.au/downloads/2008_Papers/Anthony%20Dickson.pdf

McFarland M,(2001) "Biosolids Engineering" McGraw Hill

Editor : Hall K (2006) "The Green Building Bible", Ed3, Vols 1 & 2, , Green Building Press, Llandysul

Hastings R. & Wall M. (2007) Sustainable solar housing, Earthscan

7.0 Appendices

7.1 Appendix A: Project Specification

USQ UNIVERSITY OF SOUTHERN QUEENSLAND

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/2- Research Project
PROJECT SPECIFICATION

FOR: Nicholas Gould

TOPIC: Conceptual design of a Sustainable Energy-Waste Solution for a Residential House as a basis for a Comparative Study with established 6 Star Building Designs in high-rise Buildings

SUPERVISOR: Steven Goh

PROJECT AIM: The project endeavors to derive a conceptual design for the residential sector based on innovations and lessons learned from the house design and construction of the Smart & Sustainable Homes program in QLD and to compare that to CH2.

General Research

- To provide a literature review of innovations in the Sustainable Housing and Green Building sector; and specifically,
- To research the sustainable building principles employed in the CH2 building, a world leader in sustainability;
- To research the sustainable building principles employed in Queensland's Smart and Sustainable Homes Program (SSHP);
- Research the Green Star rating system as well as other rating systems; and
- To develop an appropriate research methodology to investigate the specific goals.

Specific Goals

- Investigate and evaluate Energy and Waste solutions employed in SSHP and CH2
- Investigate and evaluate alternate energy-waste solutions from literature;
- Determine influencing factors in the selection of Energy and Waste technologies;
- Evaluate and select a rating System, or other means of comparison;
- Compare the conceptual design solution to the design in CH2 & SSHP;
- Create a decision-making matrix for the Residential Construction Sector (time permitting).

AGREED N Gould (Student) __________ (Supervisor)
Date: 16 / 3 / 9 Date: 20 / 3 / 09

Examiner/Co-Examiner __________ 31/03/09

7.2 Appendix B: Gold Coast Case Study

Gold Coast QLD

NEW HOME
ZONE 2: Warm humid summer, mild winter

Topics covered	
Passive design	
Lifestyle modification	
Rainwater harvesting	
Waste reduction	
Recycled/renewable material use	
Greenhouse gas reductions	
Indoor air quality	
Reducing water use	
AccuRate (thermal comfort)	4.8 (regulatory)

This home was designed and built to be good for the environment and avoid possible building related impacts on the health of its occupants. It has succeeded by reducing energy, water and non-renewable resource consumption, minimising waste output and use of toxic substances and materials.

The Healthy Home Project brought together Queensland's leading Universities and Government Departments in a joint venture with industry partners. For more information see www.healthyhome.com.au

This two storey, part reinforced fibre cement (FRC) and part corrugated steel-clad modern Queenslander was built as a sanctuary to nurture children in a healthy environment. It was designed to consume less energy in construction and operation. In construction this was through strategies such as using low embodied materials – timber and FRC as well as using recycled materials – hard wood timber from demolished buildings. High performance passive design provides comfort for most days of the year and negates the need for mechanical air conditioning.

Located on the Gold Coast just 200m from the beach, this healthy home demonstrates what can be achieved in sustainable housing in a sub tropical climate and where issues of overshadowing, reduction of airflow, and glare create a significant challenge for passive design.

The house was designed to work with the climate and respect the site. Due to the challenging nature of the site and associated mesoclimate some compromises were made – for instance orientation for solar heating in winter.

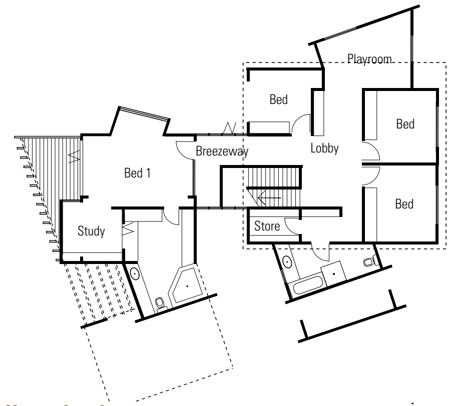
The house is designed to significantly reduce impacts on resources, both in construction and during the life cycle of the building.

Centre for Sustainable Design, University of QLD

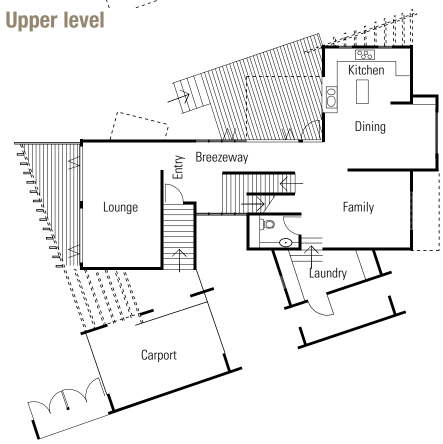
DESIGN SOLUTIONS

The house has its longest façades orientated south-east and north west creating the need for appropriate shading to provide solar access in winter and solar exclusion in summer. Two pavilions are linked by a common louvred breezeway.

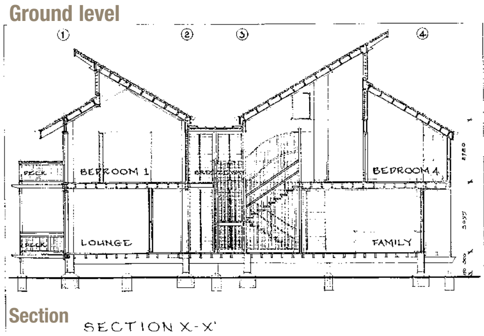
Raised, suspended timber decks are used at the entry and elsewhere for outdoor living. The pavilion plan with its open section provides good cross ventilation. The factory prefabricated skeletal laminated timber frame system has been used to provide internal planning flexibility and maximises openings for ventilation.



Upper level



Ground level



Section

The downstairs open plan kitchen, dining and family areas are also linked through entry and breezeway to a formal downstairs lounge. All have 2.7m ceilings with cathedral ceilings for the bedrooms. The use of the breezeway and a water feature promotes ventilation and evaporative cooling between the pavilions.

Suspended timber floors are used on the lower storey; FRC skirts are used around the perimeter to prevent air movement and enhance ground connectivity. The aim is to achieve similar thermal effect to mass construction which evens out day/night temperatures.

Detached utility, bathrooms and storage areas buffer living areas from westerly sun and associated heat gain.

Interior atrium space with recycled timber and stainless steel wire balustrades promotes convective cooling in calm summer conditions, mitigates overheating and allows ample light into living areas without glare. [See: 4.2 Design for Climate; 4.3 Orientation; 4.6 Passive Cooling]

INSULATION

Thorough draught proofing (including door and window seals) exclude sound, rain, cold draughts, dust, light, insects and vermin. This reduces overall heat loss by 12 per cent which is a cost effective method for saving energy.

Two forms of insulation are used – radiant (aluminium foil backed felt) and bulk insulation to address extreme solar conditions of the site.

For walls, radiant barriers are used on all walls-not just east and west which is common. A high performance specification was used comprising these layers. The outside layer behind the FRC comprises a ‘breather wall' radiant insulation layer which allows free passage of air and water vapour through the breather sheet to avoid condensation. An additional radiant layer in a concertina configuration provides two reflective air spaces for efficient insulation.

The aluminium foil insulation shown above with a 25mm reflective air gap each side stops 97 per cent of radiant heat. It is economical, efficient, non-irritant, non-allergenic and recyclable. An under roof insulation blanket provides condensation insulation to the steel clad roof and walls. [See: 4.7 Insulation]

WINDOW

Casement and louvre windows are used with plantation timber frames pretreated with penetrating timber stain for high durability and low maintenance. Louvre windows provide maximum ventilated window space, controlled indoor airflow and air exchange. Window glazing systems were carefully analysed early in the design stage and also adapted during early occupancy. Some louvre blades where changed from glass to timber to improve privacy and assist with glare reduction.

Casement windows are mainly used on the north east facing facade and comprise timber frames, timber bifolds, and french doors.

All windows are fitted with body tinted blue tint glazing to reduce ambient solar radiation and for visual effect. The body tinted glass whilst less effective than some glasses for mitigating direct solar radiation, does reflect and absorb a significant amount of infra-red heat energy and reduces the transfer of heat into the home, whilst also admitting daylight. [See: 4.10 Glazing]

Excellent quantities of daylighting are necessary for energy conservation (avoiding the need for electric lights to be kept on during the day) but the quality must be carefully controlled. The blue body tinted glass controls the visible light transmission and combined with the shading and window design creating an interior which is effectively illuminated by natural light. Electric lighting is not needed in daytime.

Central to the daylighting is strategy. North exposed window hoods provide passive solar control for summer cooling and winter warmth. Pelmeted roman and roll blinds are equivalent to R0.5 insulation on windows reducing winter heat loss. They also reduce summer glare and direct light penetration.

Adjustable shade cloths maximise daylighting whilst providing solar control on east and west exposures.

MATERIALS USE

The pre-painted steel roof with clerestory pop-outs is resilient, versatile, light and corrosion resistant. It is 70 per cent recycled, has superior strength and collects drinking water quality rainwater. It is also thermally efficient and has a very good product life span.

FRC cladding is manufactured with minimal environmental impact, has low embodied energy and an excellent lifespan. The ingredients (cellulose fibre, portland cement and sand) are non combustible and termite resistant, easy to work with, durable, low maintenance, versatile, flexible, easy to paint and resistant to weathering.

The volume of concrete was minimised though selection of the skeletal structural system, only pad footings were need as compared to a slab. Further efficiencies in embodied energy and water were achieve by using recycled aggregate and low embodied energy cement.

Solid recycled and plantation timber cabinets were used to minimise off-gassing.

Recycled Australian hardwood timbers were also used throughout to re-use resources. Tongue and groove flooring, posts, railings, stairs, floor and decking timber and joinery were all remilled.

De-nailed, stress graded, recycled structural hardwood and decking timber was used to reduce embodied energy. Timber doors and windows from sustainable forest plantation hoop pine were installed throughout the home.

The engineered timber structural frame was prefabricated in a factory. This reduced waste and site impact, limited excavation and sped up the construction.

INTERNAL FINISHES AND INDOOR AIR QUALITY

Lime wash paints were used because they are made from natural pigments with low environmental impact in manufacture. The amount of harmful off-gassing, does not exceed detectable limits which provides optimum indoor air quality for a low life-cycle cost.

Natural oil timber finishes were used externally and internally as well as non VOC emitting waterproofing also helped maintain optimum indoor air quality.

A ducted vacuum system effectively cleans the carpets; the system is quiet – dirt and dust are deposited into the unit dustbin and not recirculated throughout the home. It provides clean air and has four-stage filtration for more efficiency and longer machine life.

WATER

A water flow control system reduces water use by up to 50 per cent and controls the amount of hot water used, saving heating energy. This system eliminates dangerous and annoying temperature fluctuations in the shower, balancing the hot and cold water system.

The triple filtered rainwater storage system has a self-cleaning filter. Dirt and pollutants bypass the tank and pass through a 30 micron filter. The storage system is food-grade ‘aquaplate’, with a patented diversion system and 20 year warranty.

A 22,500L concrete rain water tank is installed for storage and utilisation of rain water in the laundry, kitchen, bathrooms and garden sub-surface watering system.

The first flush device using a treatment and water filter ensures drinking water quality and has a manually controlled mains refill capacity for when the stored rainwater runs low.

Ultraviolet water disinfection ensures pure, healthy drinking water. Polypropylene piping ensures a high quality uncontaminated water supply for life.

High-density polyethylene plumbing and ducting used is highly durable, highly recyclable and contains no heavy metal stabilisers.

A greywater treatment system allows for greywater re-use and will reduce the load on the council treatment plant when fully operational. [See: 7.2 Reducing Water Demand; 7.4 Wastewater Re-use]

ELECTRICAL SYSTEM

Energy and water efficient white goods are used. They are 95 per cent recyclable, create less greenhouse gas and have a low life-cycle cost. They conform to the best energy and water conservation standards.

A grid connected photovoltaic array has been installed and is being monitored. The system aims to supply the home and export surplus energy to the grid while producing no greenhouse gases.

Electrical cables are made from HDPE. These are self extinguishing and reduce the intensity and toxicity of smoke generated in a fire. Energy efficient lighting was used to save energy, reduce costs and hazardous material content.

LANDSCAPING

Rock paths linking balconies meander through a permaculture garden that provides fresh herbs and fruit. Native plants attract fauna and complement the landscape. The free form rock paving and pebbles used in landscaping have a low environmental impact and are functional, durable, low maintenance and have low embodied energy. These materials are readily available, recyclable and cost effective.

A recycled tyre, subsurface drip-filter irrigation system in the garden minimises water usage for maximum benefit and may be connected to the greywater system in the future. [See: 2.4 Sustainable Landscapes]

EVALUATION FROM CLIENT

The client “aimed to produce a benchmark blueprint residential development with the help of experts in order to research and inform people about environmentally friendly and energy efficient design and building techniques”.

They concluded that they “now benefit from optimum indoor air quality in a passively controlled, comfortable and functionally aesthetic house that has low running costs and low environmental impact. We have become more aware of our daily habits and use of energy, water and other resources.

It has given us great pride in our achievements and an ability to encourage others to follow in our footsteps”.

PROJECT DETAILS	
Architect:	Professor Richard Hyde. University of Sydney,
Designer:	Ted Gardner, Department of Natural Resources Queensland.
Builder:	Chelbrooke homes

Principal author:
Professor Richard Hyde

Photos:
Courtesy of the Centre for Sustainable Design, University of QLD

7.3 Appendix B: Basix Assessment Sheets.

BASIX Report

Building Sustainability Index www.basix.nsw.gov.au

Description of project

Project address	
Project name	Nic-Gould-Test-1 (copy of)
Street address	7 Right Way David Wenham 2485
Local Government Area	Tweed Shire Council
Plan type and plan number	Deposited Plan 2012
Lot no.	777
Section no.	0
Project type	
Project type	separate dwelling house
No. of bedrooms	3
Site details	
Site area (m²)	1050
Roof area (m²)	278
Conditioned floor area (m2)	214
Unconditioned floor area (m2)	36
Total area of garden and lawn (m2)	600
Assessor details and thermal loads	
Assessor number	n/a
Certificate number	n/a
Climate zone	n/a
Area adjusted cooling load (MJ/m².year)	n/a
Area adjusted heating load (MJ/m².year)	n/a
Other	
none	n/a

Score

Water: 72 (Target 40)

Thermal comfort: pass (Target pass)

Energy: 61 (Target 40)

Schedule of BASIX commitments

The commitments set out below regulate how the proposed development is to be carried out. It is a condition of any development consent granted, or complying development certificate issued, for the proposed development, that BASIX commitments be complied with.

Water Commitments	Show on DA plans	Show on CC/CDC plans & specs	Certifier check
Landscape			
The applicant must plant indigenous or low water use species of vegetation throughout 300 square metres of the site.	✓	✓	
Fixtures			
The applicant must install showerheads with a minimum rating of 3 star in all showers in the development.		✓	✓
The applicant must install a toilet flushing system with a minimum rating of 4 star in each toilet in the development.		✓	✓
The applicant must install taps with a minimum rating of 6 star in the kitchen in the development.		✓	
The applicant must install basin taps with a minimum rating of 6 star in each bathroom in the development.		✓	
Alternative water			
Rainwater tank			
The applicant must install a rainwater tank of at least 10000 litres on the site. This rainwater tank must meet, and be installed in accordance with, the requirements of all applicable regulatory authorities.	✓	✓	✓
The applicant must configure the rainwater tank to collect rain runoff from at least 200 square metres of the roof area of the development (excluding the area of the roof which drains to any stormwater tank or private dam).		✓	✓
The applicant must configure the rainwater tank so that overflow is diverted to a stormwater tank.		✓	✓
The applicant must connect the rainwater tank to:			
• all hot water systems in the development		✓	✓
• all indoor cold water taps (not including taps that supply clothes washers) in the development		✓	✓
Stormwater tank			
The applicant must install a stormwater tank with a capacity of at least 2000 litres on the site. This stormwater tank must meet, and be installed in accordance with, the requirements of all applicable regulatory authorities.	✓	✓	✓

Water Commitments	Show on DA plans	Show on CC/CDC plans & specs	Certifier check
The applicant must configure the stormwater tank to collect overflow from the rainwater tank.		✓	✓
The applicant must configure the stormwater tank to collect runoff from:			
• at least 50 square metres of roof area of the development (excluding the area of the roof which drains to any rainwater tank or private dam)		✓	✓
• at least 50 square metres of impervious areas		✓	✓
The applicant must connect the stormwater tank to:			
• all toilets in the development		✓	✓
• the cold water tap that supplies each clothes washer in the development		✓	✓
• a sub-surface or non-aerosol irrigation system, or if the stormwater has been appropriately treated in accordance with applicable regulatory requirements, to at least one outdoor tap in the development (Note: NSWHealth does not recommend that stormwater be used to irrigate edible plants which are consumed raw.)		✓	✓
Greywater diversion system			
The applicant must install a greywater diversion system on the site. This system must meet, and be installed in accordance with, the requirements of all applicable regulatory authorities.		✓	✓
The applicant must configure the greywater diversion system so that greywater for diversion is collected from:			
• the laundry		✓	✓
• each bathroom (but not the toilets)		✓	✓
The applicant must connect the greywater diversion system to:			
• a sub-surface irrigation system (Note: NSWHealth does not recommend that greywater be used to irrigate edible plants which are consumed raw.)		✓	✓

Thermal Comfort Commitments	Show on DA plans	Show on CC/CDC plans & specs	Certifier check
Floor, walls and ceiling/roof			
The applicant must construct the floor(s), walls, and ceiling/roof of the dwelling in accordance with the specifications listed in the table below.	✓	✓	✓

Construction	Additional insulation required (R-Value)	Other specifications
floor - concrete slab on ground	nil	
external wall - external insulated façade system (EIFS) (façade panel:100mm)	nil	
ceiling and roof - flat ceiling / pitched roof	ceiling: nil (down), roof: foil backed blanket (100mm)	3 wind-driven ventilator(s) + eave vents; light (solar absorptance < 0.475)

Note	Insulation specified in this Certificate must be installed in accordance with Part 3.12.1.1 of the Building Code of Australia.

Thermal Comfort Commitments	Show on DA plans	Show on CC/CDC plans & specs	Certifier check
Windows, glazed doors and skylights			
The applicant must install the windows, glazed doors and shading devices described in the table below, in accordance with the specifications listed in the table. Relevant overshadowing specifications must be satisfied for each window and glazed door.	✓	✓	✓
The dwelling may have 1 skylight (<0.7 square metres) and up to 2 windows/glazed doors (<0.7 square metres) which are not listed in the table.	✓	✓	✓
The following requirements must also be satisfied in relation to each window and glazed door:	✓	✓	✓
• Except where the glass is 'single clear' or 'single toned', each window and glazed door must have a U-value no greater than that listed and a Solar Heat Gain Coefficient (SHGC) +/-10% of that listed. Total system U-values and SHGC must be calculated in accordance with National Fenestration Rating Council (NFRC) conditions.			✓
• The leading edge of each eave, pergola, verandah, balcony or awning must be no more than 500 millimetres above the head of the window or glazed door, except that a projection greater than 500 mm and up to 1500 mm above the head must be twice the value in the table.	✓	✓	✓
• Pergolas with polycarbonate roof or similar translucent material must have a shading coefficient of less than 0.35.		✓	✓
• Unless they have adjustable shading, pergolas must have fixed battens parallel to the window or glazed door above which they are situated, unless the pergola also shades a perpendicular window. The spacing between battens must not be more than 50 mm.		✓	✓
The applicant must install the skylights described in the table below, in accordance with the specifications listed in the table.	✓	✓	✓

Skylight no.	Maximum area (square metres)	Type	Shading
S1	1.0	timber, low-E/double/argon fill	no shading

Window/glazed door no.	Orientation	Maximum area (square metres)	Type	Shading	Overshadowing
bed 3	N	2.0	timber or uPVC, toned/air gap/clear (U-value:3.64, SHGC:0.42)	eave/verandah/pergola/balcony 751-900 mm	not overshadowed
lounge	N	2.0	timber or uPVC, toned/air gap/clear (U-value:3.64, SHGC:0.42)	eave/verandah/pergola/balcony 751-900 mm	not overshadowed
living	N	4.0	timber or uPVC, toned/air gap/clear (U-value:3.64, SHGC:0.42)	eave/verandah/pergola/balcony 751-900 mm	not overshadowed

Window/glazed door no.	Orientation	Maximum area (square metres)	Type	Shading	Overshadowing
dining	N	2.0	timber or uPVC, toned/air gap/clear (U-value:3.64, SHGC:0.42)	eave/verandah/pergola/balcony 751-900 mm	not overshadowed
dining	E	4.0	timber or uPVC, toned/air gap/clear (U-value:3.64, SHGC:0.42)	eave/verandah/pergola/balcony 601-750 mm	not overshadowed
kitchen	S	2.0	standard aluminium, single clear (or U-value:7.63, SHGC:0.75)	eave/verandah/pergola/balcony 601-750 mm	not overshadowed
Bed 1	S	2.0	standard aluminium, single clear (or U-value:7.63, SHGC:0.75)	eave/verandah/pergola/balcony 601-750 mm	not overshadowed
Bed 2	S	2.0	standard aluminium, single clear (or U-value:7.63, SHGC:0.75)	eave/verandah/pergola/balcony 601-750 mm	not overshadowed
Bath	S	2.0	standard aluminium, single clear (or U-value:7.63, SHGC:0.75)	eave/verandah/pergola/balcony 601-750 mm	not overshadowed

Energy Commitments	Show on DA plans	Show on CC/CDC plans & specs	Certifier check
Hot water			
The applicant must install the following hot water system in the development, or a system with a higher energy rating: solar (gas boosted) with a performance of more than 45 RECs.	✓	✓	✓
Cooling system			
The applicant must install the following cooling system, or a system with a higher energy rating, in at least 1 living area: ceiling fans; Energy rating: n/a		✓	✓
The applicant must install the following cooling system, or a system with a higher energy rating, in at least 1 bedroom: ceiling fans; Energy rating: n/a		✓	✓
Heating system			
The living areas must not incorporate any heating system, or any ducting which is designed to accommodate a heating system.		✓	✓
The bedrooms must not incorporate any heating system, or any ducting which is designed to accommodate a heating system.		✓	✓
Ventilation			
The applicant must install the following exhaust systems in the development:			
At least 1 Bathroom: no mechanical ventilation (ie. natural); Operation control: n/a		✓	✓
Kitchen: no mechanical ventilation (ie. natural); Operation control: n/a		✓	✓
Laundry: natural ventilation only, or no laundry; Operation control: n/a		✓	✓
Artificial lighting			
The applicant must ensure that the "primary type of artificial lighting" is fluorescent or light emitting diode (LED) lighting in each of the following rooms, and where the word "dedicated" appears, the fittings for those lights must only be capable of accepting fluorescent or light emitting diode (LED) lamps:			
• at least 3 of the bedrooms / study; dedicated		✓	✓
• at least 2 of the living / dining rooms; dedicated		✓	✓
• the kitchen; dedicated		✓	✓
• all bathrooms/toilets; dedicated		✓	✓

Energy Commitments	Show on DA plans	Show on CC/CDC plans & specs	Certifier check
• the laundry; dedicated		✓	✓
• all hallways;		✓	✓
Natural lighting			
The applicant must install a window and/or skylight in 2 bathroom(s)/toilet(s) in the development for natural lighting.	✓	✓	✓
Other			
The applicant must install a gas cooktop & gas oven in the kitchen of the dwelling.		✓	
The applicant must construct each refrigerator space in the development so that it is "well ventilated", as defined in the BASIX definitions.		✓	
The applicant must install a fixed outdoor clothes drying line as part of the development.		✓	
The applicant must install a fixed indoor or sheltered clothes drying line as part of the development.		✓	

Legend
In these commitments, "applicant" means the person carrying out the development.
Commitments identified with a ✓ in the "Show on DA plans" column must be shown on the plans accompanying the development application for the proposed development (if a development application is to be lodged for the proposed development).
Commitments identified with a ✓ in the "Show on CC/CDC plans and specs" column must be shown in the plans and specifications accompanying the application for a construction certificate / complying development certificate for the proposed development.
Commitments identified with a ✓ in the "Certifier check" column must be certified by a certifying authority as having been fulfilled, before a final occupation certificate(either interim or final) for the development may be issued.